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Economic Implications of Interregional Trade Liberalization in the Canadian Dairy Industry

by

Oliver Yue Zhao ©

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Abstract

The principal objective of this study is to investigate the economic impact of the adjustment of the supply management system and the removal of inter-provincial trade barriers on the Canadian dairy industry. To examine this economic impact, this study applies a hedonic, multi-product, multi-level, and multi-regional quadratic spatial equilibrium mathematical model to simulate the Canadian dairy industry. Positive Mathematical Programming methods are applied in the model to obtain the marginal costs of milk production and milk processing and to calibrate the baseline model. Based on estimates of data for the base dairy year of 1995, the proposed modeling approach seems to provide a reasonable approximation of the Canadian dairy industry, including dairy farming, dairy processing and consumption.

Scenarios representing current and proposed policy options are identified and modeled in this study. The empirical partial spatial price equilibrium model is applied to simulate and examine the impact of each policy scenario on the Canadian dairy industry. The results of the analysis suggest that the partial or total removal of interregional trade barriers will improve the efficiency of resource allocation but will not significantly affect the domestic production and consumption of dairy products. Total welfare of Canadian dairy producers and dairy consumers increases with each scenario relative to the baseline scenario. In all scenarios of inter-provincial trade liberalization, consumers gain from the removal of barriers. After total removal of the milk-marketing quota, assuming retention of import restriction, the welfare for both milk producers and dairy processors will

increase in most provinces. Model results suggest that the producer surplus for both milk production and milk processing will to increase at the national level due to the increase in total production of raw milk and processed dairy products. Model results also suggest that total welfare would increase by 1.39% or $267 million, compared with baseline levels after removing quota restrictions limiting inter-provincial trade in the Canadian dairy industry.

Dedication

This thesis is dedicated to my parents. Without their love, support, encouragement, and sacrifices, this thesis would not exist.

I also dedicate this thesis in loving memory of my grandmother who left me peacefully when I was pursuing my Ph.D. abroad.

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Chapter 1 Introduction

1.1 Background

The dairy industry is an important sector of the Canadian economy, accounting for 13.7% of all processing sales in the food and beverage industry in 1996. In the 1996/1997 dairy year, dairy farming generated more than $3.9 billion in farm cash receipts, ranking third behind beef and grain production in Canada. Meanwhile dairy products manufactured and shipped from 278 processing plants were valued at over $8 billion. The dairy-processing sector employs just under 23,000 people and is ranked second for employment in the food processing sector, after meat products (Canadian Dairy Commission 1997b).

The Canadian dairy sector has a long history of government regulation and protection (e.g., Barichello et al. 1987, Ewing 1994, Veeman 1988). Since the supply management system was instituted in 1971, many critics have argued that this system has led to a decrease in aggregate welfare through inefficiency in resource use (Schmitz and Schmitz 1994). Josling (1981) and Barichello (1982) have estimated the annual aggregate welfare loss attributable to supply management in the Canadian dairy industry to be in the range of $215 million to $275 million.

Much of the criticism of the supply management system focuses on the aggregate social cost associated with the setting of the provincial milk-marketing quota. However, this cost may be even greater if one considers the lack of flexibility in inter-provincial movement of milk products. Veeman (1982) argues that provincial milk marketing boards have successfully exerted monopoly power in pricing and output decisions for fluid milk, resulting in real social costs. In another study, Veeman (1987b) concludes that the National Supply Management program tends to limit the extent of inter-provincial trade in the regulated commodities. Veeman argues that high and increasing quota values are a policy signal that should lead to increased market supplies and reduced levels of regulated prices rather than restrictions on quota transfer. Hollander (1993) argues that since production levels for each province are set by committees and not by the interplay of supply and demand, and given the general lack of flexibility in inter-provincial movement of dairy commodities, increased regional specialization has been slowed, resulting in inefficient resource use.

In recent years, a move towards freer inter-provincial trade in the Canadian dairy industry has been considered by many as one of crucial steps necessary to improve its overall performance. In addition, discussions have taken place within Canada concerning reductions in inter-provincial trade barriers for a number of products. Barriers to inter-provincial trade are the programs, policies, and practices of the federal, provincial, and territorial governments that restrict the free movement of dairy products within Canada under the supply management system (Kirkpatrick and Govindasamy 1994). Many of these programs affect regional or provincial patterns of dairy production and trade. For example, inter-provincial barriers have restricted the transfer of the milk marketing quota between provinces[1] and also the movement of raw milk and fluid milk products.

In addition, the impact of international trade discussions and international trade agreements may well result in changes to domestic dairy policy. A distinct possibility

[1] Limited amounts of milk quota may now be transferred between provinces as a result of regional pooling agreements.

exists that Canada will eventually have a single dairy market policy,[2] allowing more movement of raw milk and processed dairy products between provinces. These changes are likely to affect the future structure of the Canadian dairy industry.

1.2 Research Problem

Previous studies of the Canadian dairy industry have largely focused on the aggregate welfare costs associated with supply management and the effect of removing international trade barriers on the dairy industry. Little work has been done to investigate the potential economic impact associated with the removal or reduction of inter-provincial barriers.

Mussell's (1993) study examines the possible inter-provincial transfer of raw milk and quota, and concludes that both raw milk and quotas would be expected to move between provinces.[3] Another study by Lambert et al. (1995), focuses on milk production in two provinces, Ontario and Quebec. The findings suggest that if trade barriers had been eliminated in 1992, Quebec would have seen its provincial quota increased by 3.4 percent while Ontario would have lost 5.1 percent of its quota. A corresponding shift in milk production from Ontario to Quebec would have occurred. In a study focusing on reallocation of industrial quotas, Ewasechko and Horbulyk (1995) conclude that reallocation of existing quotas across farms and provinces has the potential to

[2] Currently, market policies for industrial milk and fluid milk are different.

[3] However, Mussell's study ignores the dairy-processing sector and includes only two products: industrial milk and fluid milk.

considerably reduce the costs of industrial milk production and transporting manufactured products.

It is expected that changes to inter-provincial barriers would have significant implications for Canadian dairy producers, processors, and consumers. Depending upon the relative efficiencies for different regions and associated transportation costs, significant shifts in the location of dairy production and processing might occur within Canada.

In the near future, Canada may be placed in a position whereby changes have to be made in dairy supply management regulations. These changes are likely to be based on both political and economic considerations. Therefore, it is useful to know what, how, and by how much consumption and production will change after the reduction or removal of inter-provincial trade barriers. Specifically, this information is of value to policy makers and other stakeholders who will participate in the decision making process.

In order to examine the potential impacts on production, processing, consumption and social welfare from a partial or total removal of inter-provincial barriers, several modeling challenges must be addressed. Specially, what empirical model can be used to represent the Canadian dairy industry? This question is important given the multi-level structure of the dairy industry (e.g. production and processing) and the inter-linkages with other related agricultural sectors. In addition, the demand for milk is "hedonic" in nature, as processors demand milk components: specifically butterfat and solids-not-fat.

There is currently a lack of information related to the impact of inter-provincial trade liberalization. Several studies have focussed on international trade issues related to dairy production (e.g., Cox et al. 1993, Doyen et al. 1996, Meilke et al. 1998). However, studies examining inter-provincial trade issues are limited in number, and tend to focus on Ontario and Quebec (e.g., Lambert et al. 1995). Thus, there is a need for a rigorous study of inter-provincial trade liberalization in the Canadian dairy sector.

1.3 Objectives

The principal objective of this study is to investigate the economic impact of the adjustment of the supply management system and the removal of inter-provincial trade barriers in the Canadian dairy industry. Specific objectives are

1. To identify and develop scenarios representing current and proposed policy options for the Canadian dairy industry.
2. To apply Positive Mathematical Programming methods to develop an empirical model capable of simulating activities in the dairy production and processing sectors under supply management in the Canadian dairy industry.
3. To use this empirical model to simulate the impact of the policy scenarios on the Canadian dairy production and processing industry.

1.4 Organization of the Thesis

The rest of this thesis is divided into seven chapters. Chapter 2 includes a brief review of the dairy industry in Canada and relevant regulations, policies and anticipated policy changes. Chapter 3 provides a review of relevant empirical studies of agricultural trade. Chapter 4 provides the basic theoretical foundation of the model. In Chapters 5 and 6, an empirical model is developed and tested and data sources for the parameters necessary to the model are discussed. Chapter 7 outlines the policy scenarios considered in the analysis, and provides a discussion as the empirical results of the study. Chapter 8 provides the conclusions of this study.

Chapter 2 Canadian Dairy Industry and Regulations

This section provides a brief overview of the Canadian dairy industry. Many authors have provided a description of the regulatory system in the Canadian dairy industry (e.g., Barichello 1982; Ewing 1994). However, less explicit attention has been given to the regulations affecting dairy trade among provinces in Canada. The following section discusses the policies and government regulations that affect or will affect inter-provincial trade for the Canadian dairy industry.

2.1 Dairy Industry Structure

The dairy industry comprises primarily two vertically related sectors: the dairy-production sector and the dairy-processing sector. The raw milk produced by dairy farmers is both the final product of the dairy-farming sector and the input to the dairy-processing sector. Although all final dairy products use raw milk as input, there are two usage markets for Canadian dairy farmers: the "fluid milk" market and the "industrial milk" market. Fluid milk (i.e., raw milk used to produce table milk and fresh cream) accounted for 40% of the total milk produced in Canada, or 26.8 million hectoliters in 1995 the dairy year (CDC 1997b). Industrial milk (i.e., raw milk used to manufacture dairy products such as butter, cheese and ice cream) accounted for the remaining 60%, or 44.8 million hectoliters of milk (CDC 1997b).

2.1.1 Dairy Production Sector

The dairy-farming sector includes all individuals who produce raw milk and market that milk to others, primarily processors. The typical Canadian dairy farm is quite specialized, with most of its revenue coming from milk production and the sale of dairy cattle (CDC 1998a). As of January 1995, Canada had approximately 25,700 dairy farms that owned 1.3 million cows (CDC 1997b). As shown in Table 1, about 79% of Canada's dairy farms are in Ontario (33%) and Quebec (46%), 15% in the Western provinces, and 6% in the Atlantic provinces. About 73% of Canada's dairy cows are in Ontario (33%) and Quebec (40%), 23% in the Western provinces, and 4% in the Atlantic Provinces (CDC 1998a).

In the 1995-1996 dairy year, dairy farming ranked third behind grains and red meats in terms of value of production in Canada (CDC 1997a). Production is particularly important in Quebec where dairy is the largest agricultural sector and accounts for 34% of farm cash receipts (Ewing 1994). In the Atlantic Provinces, British Columbia and Ontario, milk production ranks among the top two agricultural sectors, accounting for over 20% of farm cash receipts. Industrial milk production is proportionately higher in Quebec which includes 45% of national cash receipts from dairy but only 26% of total population, and lower in the other provinces such as British Columbia, which accounts for 11% of the Canadian population but only 5% of dairy farm cash receipts (Ewing 1994).

The Canadian domestic dairy market is supplied primarily by Canadian milk production. Although the amount of milk produced has remained almost constant in the last 20 years, the numbers of farms have steadily declined from 72,500 in the 1976 dairy year to 23,871 in the 1996 dairy year (CDC 1998b). This trend suggests that the average dairy farm in Canada is becoming larger in term of milk produced per farm.

Table 1. Numbers of Dairy Farms and Dairy Cows, and Quantity of Milk Production, by Province (1995)

Province	Dairy Farms	Dairy Cows	Fluid Milk	Industrial milk
	Number	1,000 head	1,000 hectoliter	1,000 hectoliter
Newfoundland	Not Available	4.50	Not Available	Not Available
P.E.I.	485	18.30	149.16	804.76
Nova Scotia	491	26.90	1092.04	611.82
New Brunswick	407	22.30	655.07	568.37
Quebec	11782	507.00	6823.00	20813.50
Ontario	8509	421.00	9857.01	13970.19
Manitoba	1108	56.00	1094.92	1713.47
Saskatchewan	763	44.00	883.69	1184.09
Alberta	1272	98.00	2769.97	2959.32
British Columbia	883	78.00	3519.73	2207.46
Canada Total	25700	1271.50	26844.59	44832.98

Source: Milk production figures are obtained from Statistics Canada CANSIM Matrix 5650
Numbers of farms are obtained from the CDC (http://www.dairyinfo.agr.ca/tab2.html) August 1998
Numbers of livestock are obtained from *Livestock Statistics* (Statistics Canada, August 1996a).

2.1.2 Dairy Processing Sector

The dairy products processing sector includes all manufacturing of final dairy products; specifically, fluid milk products and industrial milk products. Fluid milk products consist of standard milk (i.e., 3.5% butterfat), lower fat milk (i.e., 1% to 2% butterfat), skim milk, buttermilk, chocolate milk, and fresh cream. Industrial milk products include cheese, butter, ice cream, condensed whole milk products, powdered milk products, and semi-fluid products (e.g., yoghurt, whey). The numbers of plants and quantities of dairy products shipped from each province in 1995 are presented in Table 2.

In 1995, the Canadian dairy-processing sector was comprised of 270 dairy-processing plants (CDC 1998a). Of these plants, 161 were primarily industrial milk plants, and 109 were fluid milk processing operations. These 270 plants used 77.5 million hectoliters of raw milk and shipped dairy products valued at $7.7 billion. Second only to meat processing, the dairy-processing sector accounts for over 14% of the estimated value of all food- and beverage- industry shipments in Canada. The dairy-processing sector employs more than 23,000 people, pays approximately $831 million in wages, and is ranked as the second highest sector in the food processing sector after the meat sector in term of total employment numbers (CDC 1998b). The Canadian dairy processing industry is centered in Ontario and Quebec. Census data for 1995 indicate that Ontario had the greatest number of plants (i.e., 104 plants) and the highest value ($2.9 billion) of shipments, while Quebec (72 plants) had shipments valued at $2.8 billion (CDC 1998b). There were 62 processing plants in the Western provinces and 22 plants in the Atlantic Provinces.

The total number of dairy-processing plants has decreased steadily in Canada. Significant rationalization is occurring in the processing sector as plants strive to achieve the greater efficiencies and economies of scale required to remain competitive in increasingly global markets (CDC 1998b).

2.2 Existing Dairy Policies and Regulations

While government involvement in Canadian agriculture has a long history, the current dairy supply-management system has evolved over the last 35 years (Canadian Dairy Commission 1996). In the 1950s and 1960s, Canadian agriculture experienced market instability and persistent excess capacity. As a result, governments began to make a more extensive commitment to farm price and farm income support and to become more deeply involved in agricultural market management. The federal government created the Agricultural Stabilization Board (ASB) in 1958 to provide funds for price stabilization of various agricultural commodities including dairy products. In 1966, under the Canadian Dairy Commission Act, the Canadian Dairy Commission (CDC) was created to support the prices of processed dairy products, and the disposal of subsequent surplus products began in the 1967-68 dairy year. However, dairy farmers still considered that their prices should be increased and concluded that "the nature of the dairy industry was such that to achieve stability and a fair level of returns required stricter controls over the supply of milk"(Agriculture Canada 1990, p. 3). In the early 1970's, the concept of national supply management for industrial milk was developed with the support of the federal and provincial governments.

In 1971, Ontario and Quebec opted for "tighter" supply management and signed a Comprehensive Milk Marketing Plan. Between 1971 and 1974, the supply management system grew and more provinces joined: P.E.I. joined in 1971; Manitoba, Saskatchewan, and Alberta in 1972; British Columbia in 1973; and New Brunswick and Nova Scotia in 1974. Under this plan, now called the National Milk Marketing Plan, each producer in these provinces was allocated a certain of market share quota (MSQ), which represented the amount of milk that the producer could ship into the industrial milk market. Chaired by the CDC, the Canadian Milk Supply Management Committee (CMSMC) was created in 1975 to examine the operation of the plan, to oversee reallocation of market shares, and to develop marketing policy. The CMSMC serves as the key for policy development and discussions relating to the dairy production and processing sectors. The major part of this supply management system still shapes the current structure of the dairy industry in Canada (Agriculture Canada 1990).

Milk production is regulated both at the federal and provincial levels with quantities as well as prices (including both milk producer and processor levels) being set by regulatory agencies. The industrial milk market in Canada is controlled by the federal authority through two government bodies, the Canadian Dairy Commission (CDC) and CMSMC. The federal authority to regulate the marketing of fluid milk (e.g., milk used for table milk and cream) in inter-provincial and export trade is delegated to the provinces. Provincial milk marketing boards have primary responsibility for setting and administering fluid milk prices and quota. The provincial boards also allocate the industrial milk quota to farmers, calculate payments to farmers for milk shipments, collect levies, and negotiate with processors to determine the prices paid for milk (CDC 1997a). Some specific policies and programs are discussed below.

2.2.1 Quantity Control

The quantity of raw milk production is controlled by two types of quota: provincially regulated fluid milk quota, and a nationally regulated market share quota (MSQ) which directs milk to the industrial market. When supply management was first implemented, quotas were granted free of charge to dairy producers in an amount equal to their previous year's production. After supply management was implemented, the CMSMC controlled the MSQ and the milk board in each province managed the fluid milk quota.

The CMSMC meets at the end of July every year to set the level of MSQ for the next dairy year. MSQ is set at a level equal to domestic butterfat requirements in milk equivalents, plus export requirements minus allowable imports (Agriculture Canada 1990). Actual domestic requirements for butterfat and for solids-not-fat for the previous year are determined by the CDC using a stock reconciliation method. This method determines domestic disappearance using production, exports, and beginning and closing stock figures for major products. Butterfat requirements for the upcoming year are then determined based on utilization in the previous year and recent trends. The CMSMC then allocates MSQ to the provincial boards (Ewing 1994).

Provincial shares and national quantity of MSQ from 1980 to 1996 are presented in Table 3. From 1980 to 1996, although the total quantity of MSQ was decreased slightly from 168 to 158 million kilograms of butterfat, the share of MSQ for each province did change significantly. The largest increase in MSQ share over the period was observed in British Columbia (i.e., only 1.1%).

Provincial governments set fluid milk marketing quotas based on provincial demand for fluid products. Fluid quota usage was originally calculated on a liter per day basis, but in recent years has been converted to a kilogram butterfat basis. The fluid milk quota provides producers with the right to ship a given amount of milk per day for as long as they continue to hold quota. A producer may hold a maximum of 75% of their total combined quota volume in the form of fluid milk quota (Mussell and Goddard 1996). The remainder of the milk shipped by the producer must be covered by MSQ. Accordingly, producers in each province must maintain no less than 25% of quota as MSQ. With the exception of Alberta, MSQ and fluid quota are now held jointly by producers in the form of "blended" quota. Most provinces have set fluid quotas above the estimated provincial requirements and retroactively allocated the excess milk to industrial uses (Ewing 1994).

2.2.2 Price Control

A system of administered pricing is a central element of Canada's dairy supply management system. Both federal and provincial governments have responsibility for setting relevant prices for different uses of milk; that is, industrial milk and fluid milk.

The fluid milk price is determined by each provincial board using a cost of production (COP) formula. This COP formula differs between provinces. For example, in Alberta, the fluid milk is priced at the producer level by the Alberta Energy and

Utilities Board using a price formula determined by selected statistical indicators[4] (Appleby 1996).

The industrial milk price is set nationally by the CDC and is also based on a cost of production formula. The industrial milk price is based on a target price to be paid to farmers for industrial milk shipped within quota. The target price for industrial milk is set at the beginning of the dairy year by the CDC under Article 8 of the Canadian Dairy Commission Act (Agriculture Canada 1990). The target price is the level of return determined to be adequate for efficient milk producers to cover their cash costs and to receive a fair return on their labor and investment related to the production of milk sold for industrial purposes. The formula is based on the cost of production (COP) survey from a random sample of farms[5] located in Ontario, Quebec, New Brunswick, and Manitoba[6]. These provinces represent more than 80% of Canadian industrial milk and cream production (Agriculture Canada 1990). The COP survey calculates three major type of cost: cash costs, capital costs and labor costs. More detailed information concerning the survey is available from Ewing (1994, page 67).

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[4] The current Alberta formula is as follows:

Fluid Milk Price =

(Price of 16% Dairy Feed) * 0.14
+(price of Alfalfa Hay) * 0.14
+(Index of Farm Wages) * .12
+(Index of Farm Inputs) * 0.20
+(Index of Consumer Prices) * 0.10
+(Avg. Weekly Industrial wage) * 0.16
+(Per Capita Sales of Milk (L/month)) * 0.14

The first five factors represent the producer's major cost components and return. The weights given to these factors were established with reference to the actual cost structure on the supply side. The last two components are indices related to consumer demand. The relative demand elasticity was a guide for setting the weight of the demand side (Appleby 1996).

[5] The target price is calculated using a sub-sample of farms representing the top 70% of producers in term of cost efficiency.

[6] The cost of production survey has been expanded to all provinces in recent years.

One result of using this method of price setting (i.e., from COP surveys) is that the target price for industrial milk in Canada has increased over time, relative to U.S. and world prices (Ewing 1994). For example in 1982, the industrial milk price was almost the same for U.S. and Canada. However, by 1995, the target price for industrial milk in Canada was $53.35 and the U.S. government support price was $31.12 CND. Ewing (1994) suggests that high milk prices in Canada are due to the price setting formulas used in Canada, which are largely isolated from market to demand and supply factors. It is also suggested by Chen and Meilke (1998) that, since milk producers participating in the COP surveys know that their cost data are used to set the price of milk, that reported costs may be inflated by participating producers.

In order to achieve the target price to milk producers, the CDC operates an "offer to purchase" program, under which the CDC purchases (at the support price) butter and skim milk powder not needed immediately for the domestic market from Canadian processors. Support prices are designed to provide manufacturers of these two products with an assumed margin[7] to cover costs and provide a return on their investment. Support prices also act as floor prices in the wholesale trade of these two products and indirectly can affect the wholesale prices of all industrial dairy products.

The "offer to purchase" program has allowed the CDC to hold butter and skim milk powder stocks and related products, which could later be made available either to supply the domestic market when demand exceeded production or can be exported if not

[7] The assumed margin incorporated into the support prices for processors was set at $8.12 per hectoliter for the 1997 dairy year.

required by the domestic market (CDC 1997a). In doing so, the CDC underpins the price for all of the milk used to make dairy products for the domestic market.

Most provinces charge different prices to dairy processors depending on the end use of milk, even though the milk is identical in quality. The price difference between fluid milk and industrial milk ranges from 10% to 25% across the provinces, at a 1991 price levels (Ewing 1994). According to Ewing, these inter-provincial differences may be attributed to differing costs of production or different methods of calculating the COP.

On August 1, 1995, the beginning of the dairy year, the target price for producers was $53.35 per hectoliter of industrial milk[8]. An amount of $0.12 per hectoliter is added to the target return to cover costs associated with the normal stocks of butter held by the CDC to ensure domestic demand was met, and to cover administrative costs related to the CDC's domestic marketing activities. The processor margin was set at $7.97 to process each hectoliter of milk. The support prices for butter and skim milk powder were set at $5.324 per kilogram and $3.931 per kilogram, respectively (Dairy Farmers of Ontario 1996).

2.2.3 Direct Subsidy Program for Industrial Milk

Under the federal program of supporting the target price for industrial milk, the federal government pays dairy farmers a direct subsidy for milk produced within domestic requirements. Until 1988, the direct subsidy was paid on actual domestic requirements plus the export sleeve. Since 1989, the direct subsidy has been paid only on actual

[8] This price assumes a butterfat content of 3.6 kilograms per hectoliter of milk.

domestic requirements. The level of this subsidy was $6.03/hectoliter. The subsidy is included in the target price calculation. In 1995-96, the subsidy payment represented 8.7 percent of the target price as compared to 24 percent in 1975. Due to pressure for changes from both the domestic economic environment as well as of international trade negotiations, the federal government is gradually removeing this direct payment program. Originally, the plan was to reduce this subsidy by 15 percent each year beginning in August 1997 (CDC 1997a). However, in a recent report (Statistics Canada 1998), it was noted that the federal government has agreed to delay the subsidy rate reductions by six months. The subsidy is now being phased out gradually over a five-year period starting in February 1998 (Statistics Canada 1998).

2.2.4 Import and Export Controls

2.2.4.1 Import Controls

Import restrictions have been an integral part of the dairy supply management system in Canada. Due to border restrictions, imports of dairy products to Canada have been low. Before 1995, most products having at least 50% dairy content were on Canada's "Import Control List", which meant that they were eligible for quantitative import restrictions. Imports of other dairy products were subject to discretionary licensing whereby prospective importers were required to show that they couldn't supply their requirements from a domestic source. Imports were essentially zero for most of these products except in special circumstances.

The import control system for dairy was substantially changed when the World Trade Organization (WTO) Agreement on Agriculture came into effect on January 1,

1995. Quantitative restrictions used in the past to limit imports were replaced by tariff rate quotas as border protection. Currently, imports of certain dairy products above historic levels are subject to high over quota tariffs aimed at discouraging additional imports. These high tariffs are expected to decline by 15 percent of their value over the six years during which the current WTO Agreement on Agriculture is in effect.

2.2.4.2 Export Subsidies and Special Classes Pooling

Canadian domestic prices for dairy products are above world prices, which means that exports must be subsidized. Prior to August 1, 1995, the export subsidies were financed through funds from "within-quota levies". Exports of dairy products manufactured with over-quota production were financed with over-quota levies. Levies were collected by provincial boards or agencies and forwarded to the CDC. The December 1993 GATT agreement requires that the volume of subsidized exports must be reduced by 21% from 1986-90 levels over a six-year period and the value of export subsidies must be reduced by 36% over the same period (Ewing 1994).

In response to this change, the dairy industry implemented a national pool system. As of August 1, 1995, provinces agreed to share a common classification system for milk. Milk is now priced into five classes according to its intended use. The first four classes are for milk used to process domestic products and the pricing of milk in these classes reflects domestic requirements at the going prices. Milk used in products for export as well as milk produced over-quota fall into Class 5 and are priced according to the world price.

Producers from all provinces (except Newfoundland) share the market revenue from Class 5 sales. There is no limit to the amount of milk a producer can deliver in excess of allotted market share quota and there is no longer an levy on the over quota milk production. However, producers are paid world prices for milk production in excess of MSQ. As of August 1, 1995, over-quota production by province was to be determined monthly before the special class pool is calculated, according to a formula developed by the CMSMC (CDC 1996). Changes in this system are being made following a WTO panel ruling.

2.2.5 Regional Milk Pooling Agreement

Since August 1996, revenues from milk sales (i.e., fluid and industrial) have been pooled among the producers of Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island. This pooling agreement is known as the Eastern All Milk Pool or the P6 Agreement (i.e., the revenue from all milk sales is pooled among these six provinces). In March 1997, the four Western provinces also implemented a milk pooling arrangement (i.e., the P4 Agreement), known as the Western Milk Pool (CDC 1998b).

2.3 Implications for Internal Trade Barriers

The Agriculture Canada (1991) identified that the provincial barriers are a major factor in the existing system's lack of flexibility. According to the definition of Kirkpatrick and Govindasamy (1994), barriers to inter-provincial trade include the programs, policies, and practices of the Canadian Dairy Commission and provincial dairy market board, which restrict the free movement of products within Canada. The network of rules and regulations that been developed around the supply management system has significant impacts on the inter-provincial movement of industrial milk and fluid milk quota, raw milk and some the processed products.

2.3.1 Inter-provincial Restrictions on Fluid and Industrial Milk Quota Transfer

Under the National Milk Marketing Plan, only the CMSMC has the authority to reallocate provincial industrial milk quota. Original provincial allocating were based on historical production. It has been difficult to get agreement on redistribution of existing quota a provinces. In section I(6) of the National Milk Marketing Plan it states " the Committee shall examine the effectiveness with which milk is produced, processed and marketed in Canada" (Agriculture Canada 1990, p. 11). However, since the inception of this plan, this provision has been of little use. Veeman (1988) and Ewing (1994) provide evidence that the relative share of MSQ for each province has been relatively constant during the 1980s.

The fluid milk marketing quota is set by provincial governments based on the historical provincial demand for fluid products. Given the expense of transporting raw milk and the historically high quality requirements, the marketing of fluid milk has remained under provincial jurisdiction (Agriculture Canada 1990). Each province maintains and administers a quota scheme for fluid milk, and no mechanism exists for the trade of fluid milk quotas among provinces. As long as the provincial boards and agencies have the authority to govern the fluid milk quota setting and marketing of milk within their own jurisdiction, it is difficult for quota to be transferred or exchange between provinces.

The regional milk pooling arrangements of milk revenue (as discussed in section 2.2.5) have created the opportunity to implement a regional quota-exchange market. The Eastern and Western Pools have discussed rules for an inter-provincial quota exchange. In August 1997, the Eastern Pool established a limited inter-provincial quota exchange among Quebec, Nova Scotia and Ontario.[9]

2.3.2 Intra-provincial Restrictions on Milk Quota Transfer

Although producers may trade milk quota within each province, there are many regulations governing these trades. These restrictions include the maximum quantity of quota that a single producer is allowed to hold, minimum sales quantity of quota, restrictions on sales, etc. A detailed discussion of this regulation is beyond the scope of this study. Barichello and Chen (1997), Barichello et al. (1987), and Tallard and Curtin (1991) provide discussion of these regulations.

All these restrictions on quota movement may affect producers' incentives to pursue and adopt innovations and technical improvements, especially where the changes involve lumpy capital items with large size economies. This may be another potential restriction for the movement of quota.

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[9] This arrangement was short-lived, as both Ontario and Nova Scotia withdrew from the exchange. Both provinces cited significant net transfers of quota to Quebec producers as the reason for their withdrawal.

2.3.3 The Restriction of Raw Milk Distribution.

Under milk production regulations, no milk producer can market milk to anybody other than the relevant dairy board in each province (Dairy Farmers of Ontario 1997). As well, under the supply management system, there is no movement of industrial milk among provinces. Theoretically, only the CDC has the authority to reallocate industrial milk quota (instead of industrial milk) to reflect any changes in demand for industrial milk among different provinces.

A similar situation holds for fluid milk whose quota is determined by each provincial dairy board based on provincial demand for fluid products. For fluid milk, since it is expensive to transport raw milk and the quality requirements are high, the majority of fluid milk is historically consumed in the province in which it is produced. Thus, the development of policies concerning fluid milk has been historically a provincial responsibility (Agriculture Canada 1990).

2.3.4 The Restriction of Processed Fluid Milk Production and Distribution.

Since the setting of fluid milk quota and marketing of fluid milk is under the jurisdiction of each province, inter-provincial movement of fluid milk products is not normally observed.[10] In order to protect internal economic benefits, each provincial dairy board tends to set barriers to avoid the importation of fluid milk products from other province (Kirkpatrick and Govindasamy 1994). There are different standards for table milk production and distribution across the country. In addition, there are differences in licensing requirements for table milk distributors. The different standards for raw milk across the provinces also increase the difficulty for inter-provincial milk trade.

2.4 Summary

Based on the discussion related to Canadian dairy policy, some inferences may be make regarding possible changes to be modeled in this study. Specifically, it is conceivable that the regional pooling agreements may be expanded to regional pooling of quota. As well, it would be useful to investigate the impact of introducing special classes pooling on dairy production and processing.

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[10] Although inter-provincial trade of table milk does occur among Alberta, British Columbia, and Saskatchewan, it only because of special arrangement between those three neighboring province to permit small amount of the milk movement with some restrictions (Kirkpatrick and Govindasamy 1994).

Table 2. Number of Dairy Processing Plant and Shipments of Dairy Products by Province (1995)

	Process. Plant Number	Fluid Milk 3.5% BF	Fluid Milk 2% BF	Other Milk[1]	Cream	Ice Cream	Cheddar Cheese	Other Cheese[2]	Butter	Skim Milk Powder	Other Dairy Products[3]
Unit		Million Hectoliter	Million Hectoliter	Million Hectoliter	Million Hectoliter	Million Kilogram	Million Kilogram	Million Kilogram	Million Kilogram	Million Kilogram	Million Kilogram
Newfoundland	4	-[5]	-	-	-	-	-	-	-	-	-
P.E.I.	10	-	0.925	-	-	-	-	-	-	-	-
Nova Scotia	13	-	-	-	-	-	-	-	-	-	-
New Brunswick	5	-	-	-	-	-	-	-	-	-	-
Quebec	72	1.174	3.558	1.591	0.402	75.464	62.910	101.131	36.990	24.566	48.225
Ontario	104	1.696	5.14	2.299	0.58	140.799	31.403	65.679	32.137	18.746	48.231
Manitoba	15	0.188	0.571	0.255	0.064	17.99	7.059	0.000	4.758	-	6.622
Saskatchewan	5	-	-	-	-	-	-	-	-	-	-
Alberta	21	0.476	1.444	0.646	0.163	23.984	1.643	3.541	9.850	-	21.818
British Columbia	21	0.605	1.835	0.821	0.207	37.927	-	4.582	-	-	16.289
Other in Canada[4]	0	0.464	0.259	0.851	0.176	0.659	13.854	0.000	13.032	27.761	0.000
Canada	**270**	**4.670**	**14.158**	**6.332**	**1.599**	**5.107**	**116.869**	**174.933**	**96.767**	**71.073**	**141.185**

Source: Statistics Canada Catalogue (23-001), Downloaded from CANSIM Matrix 5653

Note:
1. Other Milk includes 1% milk and skim milk.
2. Other Cheese includes cottage cheese and processed cheese.
3. Other Dairy products include Yoghurt, Buttermilk Powder, Buttermilk and Chocolate milk and Whey Powder.
4. "Other in Canada" is the difference between the total for Canada and the sum of the available provinces.
5. "-"indicates that data are not available.

Table 3. Provincial Shares (Percentage) and Total National Industrial Milk Quota, 1980-96

	1980	1985	1991	1994	1995	1996
Newfoundland	-	-	-	-	-	-
P.E.I.	1.8	1.8	2.0	1.9	1.9	1.9
Nova Scotia	1.4	1.3	1.3	1.3	1.3	1.3
New Brunswick	1.0	1.3	1.3	1.3	1.2	1.2
Quebec	48.2	47.4	47.2	47.6	47.6	47.9
Ontario	31.9	31.2	31.0	30.9	30.5	30.6
Manitoba	3.9	3.9	3.9	3.8	3.7	3.7
Saskatchewan	2.4	2.6	2.6	2.5	2.5	2.5
Alberta	6.0	6.7	6.6	6.5	6.5	6.3
British Columbia	3.4	3.8	4.2	4.3	4.7	4.5
Canadian MSQ (Million kg of Butterfat Equivalents)	**167.6**	**172.8**	**153.9**	**157.4**	**157.9**	**157.9**

Source: 1. Canadian Dairy Commission web site (http://www.dairyinfo.agr.ca/quota2.html) March 1998 (only from 1991-1996)
2. Dairy Statistical Handbook 1984 –1985 (from 1980-1985)

Chapter 3 Review of Empirical Studies of the Canadian Dairy Industry

While few studies have investigated the potential impacts of removing inter-provincial trade barriers on dairy production allocation within Canada, a number of studies have used simulation models to analyze Canadian dairy production within the context of international trade liberalization. In order to develop an empirical model to analyze the effects of inter-provincial trade liberalization of the Canadian dairy industry, a brief review of empirical models used in previous studies of the dairy industry is provided below. Some of the relevant aspects of characteristics of these models are summarized in Table 4.

3.1 Large Scale Dairy Models Including the Canadian Dairy Industry

3.1.1 University of Wisconsin-World Dairy Model (UW-WDM)

The University of Wisconsin-World Dairy Model (UW-WDM) is a spatial equilibrium model. It was developed by Cox et al. in 1993 and revised in 1996 (Cox and Zhu 1996) to analyze the quantities and prices for dairy products in the U.S. and rest of the world. The model is based on the maximization of a quasi-social welfare function across 25 producing and consuming countries/regions which engage in the trade of dairy products. Seven dairy commodities (i.e., milk, cheese, butter, whole milk powder, skim milk powder, casein and other dairy products) and raw milk are considered in the model. The strength of the UW-WDM model is that it explicitly incorporates milk fat and solid-not-fat into the spatial equilibrium structure.

The empirical model comprises the following regions: Western Europe, Eastern Europe, the former USSR, other North Asia, Japan, South Asia, India, Other South Asia, Australia, New Zealand, Middle East, North Africa, South Africa, Canada, the United States, Mexico, Central America And Caribbean, South America and the rest of the world. Due to the large scale of the model, it lacks details regarding current and emerging trade policies for most countries, including Canada, which is included as a single region. There is no information on regional differences in milk production, processing and transportation cost within Canada. Another limitation is that this model only focuses on the dairy sector and has no links with other agricultural sectors such as the livestock, feed and grain sectors. The model incorporates supply functions with supply elasticities, but the publication does not indicate whether or how the supply functions were estimated, or the sources of supply elasticities.

3.1.2 Agricultural Simulation Model for OECD Countries[11]

The Organization for Economic Co-operation and Development (OECD) model is a dynamic supply-demand simulation model of world agriculture. The model simulates, under domestic market conditions, world prices of major agricultural commodities traded by seven OECD countries/regions (i.e., Australia, Canada, EU(12), Japan, Mexico, New Zealand and the United States) with the rest of the world. The rest of the world is

[11] The information for this model was obtained from a confidential internal OECD document.

aggregated and treated as one region. The model measures both the short run (i.e., one year) and the medium run (i.e., five year) adjustment of quantities to prices or other factors. Fluid milk, butter, cheese, and skim milk powder are four of eighteen agricultural commodities considered in the model.

This model presents an advantage over the UW-WDM model in that it includes agricultural inter-linkages between dairy and other agricultural sectors. One feature of this model is that it has no upward sloping supply response functions for countries or regions where prices are set as constant by the governments or agencies in the framework of supply management. Another feature is that the dairy market is not highly detailed in this model; it only has four dairy products and an important product, skim milk powder, is included as part of the "other dairy products" category.

3.1.3 Cornell University - Dairy Model

Doyon et al. (1996) used a partial equilibrium, multi-commodity and multi-region linear programming model (e.g., Cornell University Dairy Model or CUDM) to study the effects of trade liberalization policies on Quebec, Ontario and Northeast U.S. dairy sectors. The model includes seven dairy products (i.e., fluid milk, frozen desserts, specialty cheese, dry and condensed products, butter, yogurt and cheddar cheese), 296 supply points, 184 consumption points and 307 processing points, and balances supply and demand of milk components. The model minimizes the total production cost for all production points. Transportation cost is treated as part of the production cost in the model.

The strength of this model is that it includes details of the Northeast American dairy market and is relatively detailed in terms of the Canadian market, which includes Quebec and Ontario. It also considers the multiple component nature of raw milk. However, since the linear mathematical programming model minimizes production costs, it does not explicitly consider the welfare of consumers. Similar to other dairy models, this model does not have inter-linkages to other related agricultural sectors. It is not clear from the report that whether marketing quota restrictions for Ontario and Quebec have been considered and incorporated into the model.

3.2 Canadian Regional Agricultural Model (CRAM)

CRAM is a regional, multi-sectional, multi-level, comparative, partial equilibrium mathematical programming model of Canadian agriculture. It covers ten provinces in Canada, and includes two production levels for the Canadian dairy industry: production and processing. It simulates production, marketing and transportation of the major agricultural commodities produced in Canada. The model has approximately 2,300 variables and 1,300 equations. It optimizes the sum of a quasi-welfare function which is simplified as the areas under the demand curves minus the production cost of these commodities, for a single year within the constraints of agricultural resources and final demands for producers and consumers (Klein et al. 1993). The model represents Canada's agricultural sector with 29 crop regions producing wheat (4 grades), barley, flax, canola, corn, soybeans, hay, pasture and other crops. Livestock production is modeled at the provincial level for beef, hog, dairy and poultry. CRAM has been used in several agricultural policy studies (e.g., Graham & Moschini 1989; Graham et al. 1990; Klein et al. 1991a; and Webber et al. 1986).

CRAM incorporates links with other agricultural sectors, incorporates welfare analysis for both consumers and producers, includes a range of existing Canadian dairy policies in Canada and covers a relatively broad range of dairy products (i.e., six final dairy products). In fact, CRAM may serve as a good starting point of this study.[12] However, CRAM does have a few limitations, relative to the model requirements for this study. On the production side, dairy-processing costs are currently the same for each province for given products. Also the model does not include price responsive supply functions for either raw milk or dairy products. Instead CRAM makes the implicit assumption of constant marginal cost for dairy production and processing (i.e., marginal cost average cost).

3.3 Other Studies Related to the Canadian Dairy Industry

Recently, several studies have investigated the inter-provincial dairy trade liberalization issue from different perspectives. These studies provide many unique aspects, which can be incorporated into the current analysis. For the purpose of this study, the focus of this review is on the aspects of those studies that can be improved in the current analysis.

Mussell and Goddard's paper in 1996 studies the potential for inter-provincial milk and quota transfer in Canada. A six-equation econometric model was used in this study which included fluid demand, fluid supply, industrial supply, total milk production,

[12] More detail will be provided in Chapter 5.

retail price linkages, and industrial blend price linkages. The finding of this study indicates that the removal of provincial boundaries to trade in milk and milk quota could have significant structural impacts on the Canadian dairy industry. Mussell and Goddard (1996) found that the revenue benefit of trade in milk and quota accrue mostly to Quebec since Quebec had lower production costs and therefore would gain milk quota. Mussell and Goddard (1996) provided good documentation of data sources, which may potentially be useful for the current study. But Mussell and Goddard assumed zero transportation costs. For a nation as large as Canada, transportation costs are clearly significant. Another limiting feature of Mussell and Goddard's study was that it included two products (i.e., industrial milk and fluid milk) for dairy production, and it did not include the dairy processing sector.

Rude (1992) constructed an econometric simulation model of the Canadian dairy-processing industry to study effects of trade liberalization on the dairy-processing industry. In this study, producers' profits were aggregated to a national level in the production of five dairy products (i.e., soft products, concentrated milk, cheese, butter, and fluid milk). A system of cost functions was estimated at the national level. The findings of this study indicate that the supply management system does distort the allocation of final dairy product production, but the distortion is less than 4% of baseline solution. This study also indicate that trade liberalization leads to dairy product specialization. The focus of his study is the dairy-processing industry, in which he provided detailed analytical framework and empirical information that can by used in our study. However, a limitation of this study is that the national aggregation sacrifices a great deal of detail for each province. The applicability of the model is also limited in that only one level of market is included (i.e., raw milk production was excluded), no transportation costs are incorporated and no detail for dairy products is built into the model.

Lambert et al. (1995) constructed a econometric model using two-stage least squares for both used and unused quotas of dairy-processing industry to analyze the industrial milk quota market in Quebec and Ontario, and to evaluate the potential impacts of a unique quota market between those two provinces. They used estimated demand and supply functions to simulate free trade in quotas between the two provinces. The results of this study show that if trade barriers had been eliminated in 1992, Quebec would have seen its provincial quota increase by 3.4 percent while Ontario would have lost 5.1 percent of its quota. Their study provided a detailed analysis on quota markets in Quebec and Ontario. It also provided an interesting perspective by treating milk quota as a product and using it as the vehicle to study trade liberalization in dairy industry. It may be valuable for a similar study to extend the coverage of this study to include some dairy products and other provinces in Canada. However, this may require extensive collection of time-series data for each province.

Ewasechko and Horbulyk (1995) use a fixed allocation mathematical programming model to examine the impacts of reallocating of industrial milk quota across provinces in Canada. The objective of the optimization problem was to minimize the delivered cost of four dairy products: cheese, butter, ice cream, and yoghurt. This study concludes that reallocation of existing quota across farms and provinces has potential to considerably reduce the costs of industrial milk production and the cost of transporting manufactured products. This study demonstrates the importance of transportation costs in the Canadian dairy industry. However, it focuses solely on transportation cost and does not consider welfare gains or losses for consumers and producers.

Meilke et al. (1998) analyze the potential for increased trade in dairy products between Canada and the United States using a static, non-spatial, partial equilibrium model. In the study, they use a capital pricing model to obtain an estimate of (unobserved) marginal cost for milk production. The model has two final dairy products (i.e., fluid product and industrial product) and includes only two regions (i.e., U.S. and Canada). Data from Ontario are used as being representative of the Canadian dairy industry. Study results suggest that, after trade liberalization, the trade flows in milk and dairy products between Canada and United States are likely to be very small. This finding is largely unaffected by changes in demand and supply elasticities for fluid and industrial milk, and Canadian processing margins for milk products. This study recognized the problem of unobserved marginal cost under the supply management system and provided an interesting approach, which may be used in the current study. However, the study used a non-spatial model, which did not include transportation cost.

3.4 Desirable Properties of An Empirical Canadian Dairy Model

Several studies have used variety of models to study the Canadian dairy industry. All of these studies have both positive and negative aspects in term of modeling the dairy sector in Canada. In order to analyze the effects of inter-provincial trade liberalization for the Canadian dairy industry, the following features of an empirical model are desirable for this study:

- It should be a multi-level market model that incorporates all aspects of the dairy sector from raw milk production to dairy processed products to consumption of dairy products.
- It should be able to incorporate hedonic supply and demand relationships for the components of milk in the dairy industry.
- It should have inter-linkages to other related sectors such as livestock and grain sectors.
- It should be able to incorporate relevant policies for the Canadian dairy industry.

Of the models reviewed in this chapter, CRAM comes closest to having all of the desirable qualities for the current study.

Table 4. Empirical Dairy Model Overview

Studies	U. Wisconsin World Dairy Model	OECD Agricultural Model	Cornell Univ. Dairy Model	Canadian Regional Agri. Model	U. Guelph Study-1	U. Guelph Study-2	U. Guelph Study-3	CJAE-study
Author(s)	Cox 1993-1996	-[a]	Doyon et al. 1996	Webber, et al. 1986-1990	Mussell 1993	James Rude 1992	Meilk et al. 1996	Ewasechko & Horbulyk 1995
Type of Model	Quadratic Mathematical Programming	Dynamic Synthetic Model	Linear Mathematical Programming	Quadratic Mathematical Programming	Synthetic Model	Econometric Synthetic Model	Econometric Synthetic Model	Linear Allocation Model
Objective Function	Max. Net Social payoff	N/A[b]	Min. production cost	Max. Quasi-social welfare function	N/A	N/A	N/A	Min. transport. Cost
Single(S) or Multiple Products (M)	M	M	M	M	M	M	M	M
# of Dairy Products	6	4	7	6	10	4	2	4
Single (S) or Multiple Regions (M)	M	M	M	M	M	S	M	M
# of Regions in Canada	1	1	3	10	10	1	1	10
Links with other Sectors	No	Yes	No	Yes	No	No	No	No
# of other Agri- products	0	10	0	14	0	0	0	0
Single (S) or Multiple Level Markets (M)	S	S	M	M	S	S	M	S
Use Marginal Costs For Raw Milk Production?	Yes	No	No	No	No	No	Yes	No
Use Marginal Costs For Processing Products	No	No	No	No	No	Yes	No	No
Difference in Production Costs Across Region?	No	-	no information	No	No	-	-	no information

Note. a: represents "not available"; b: N/A represents "not applicable".

Chapter 4 Theoretical Framework

Economists have long been interested in assessing the direct and indirect impacts of alternative policies within an economy. Since the early 19th century when Ricardo outlined a theory to explain the pattern of trade and the benefit to trade participants, the construction of a general theory and empirical model of location and space has been a challenge to economists (Takayama and Judge 1971). Various methodologies have been utilized to formulate these models. In studies where the objective has included identification of a sector's structure, various econometric approaches have been taken. However, in order to simulate the effect of new policies upon a sector, mathematical programming has proven to be a particularly useful tool (McCarl et al. 1980). In his discussion of spatial economic analysis, Thompson (1989, p. 49) states: "... so far, the most common class of agricultural trade models, particularly for comparative static analysis of the effects of a change in policy, is comprised of the class of spatial and temporal price and allocation models."

Since the early 1970's, the spatial price equilibrium (SPE) model has served as a major tool of analysis for issues in agricultural trade. This includes application to the dairy sector. Doyon et al. (1996) use a partial equilibrium, multi-commodity and multi-region linear programming model to study the effects of dairy trade liberalization policies in North America. Ewasechko and Horbulyk (1995) use a linear spatial programming model to examine optimal provincial allocation of industrial milk quota. Cox and Zhu (1996) developed a large spatial equilibrium model to assess the impact of liberalization in world dairy trade. A partial equilibrium model for agriculture has also been employed within Agriculture and Agri-Food Canada to examine the implications of the Canada-U.S. Trade Agreement (CUSTA), the Multilateral Trade Negotiations (Graham et al. 1990) and the Western Grain Transportation Act (Klein et al. 1991a).

In this study, spatial equilibrium analysis will be used to study the economic effects of regional trade liberalization for the dairy sector in Canada. In the following section a discussion of the relevant theoretical background and the empirical model will be outlined.

4.1 Theoretical Framework of Trade and Spatial Equilibrium

Trade occurs between individuals because people believe that they can benefit from the process. If a market is free of trade barriers, individual traders tend to buy goods and services wherever they can obtain them most cheaply and sell them to buyers offering the highest prices. Trade between two individuals can be viewed as an attempt to increase their own utility. The same argument may be made for trade between regions or countries. Trade between two regions can be viewed as an attempt to increase total social utility.

Adam Smith was one of the first economists to recognize that trade can result in benefits or increase social welfare for all of the participating regions. According to Smith's theory of "absolute advantage," regions benefit by specializing in the production of goods for which they have an absolute advantage, and by importing goods for which they have an absolute disadvantage. A region is said to have an "absolute advantage" in the production of a good if its average production costs are lower than the costs in other countries at prevailing prices and exchange rates. However, in the real world, absolute advantage is not the only cause of trade between regions. According to Ricardo's theory of "comparative advantage," a region need not have an absolute advantage in the production of a good in order to achieve economic gains from trade. Countries or regions are said to have comparative advantage if the domestic opportunity cost (or marginal cost) of producing a good is less than the international or inter-regional price. A country or region with a comparative advantage will export this good to other regions or countries (Houck 1986).

If a region has an absolute or comparative advantage in the production of a good, relative to another region, then trade will result in economic gains for both regions. Gains from trade arise from two sources: gains from exchange and gains from specialization. Gains from exchange are a result of consumers being able to access a larger and more diverse bundle of goods and services at lower overall prices than would be possible in the absence of trade. Gains from specialization result from a region's resources being more efficiently allocated among industries in order of comparative advantage (Houck 1986).

In classical general equilibrium theory, all intermediate and final commodities as well as all producers and consumers, are treated as if they are located at one point in space. Product transfers are accomplished assuming zero time requirements and zero transfer cost. If there is free trade between regions and transfer costs are assumed to be small or zero, the equilibrium for a two-region one-commodity world is as illustrated in Figure 1.

Demand and supply relationships in regions A and B are represented by D_a and S_a, and D_b and S_b, respectively. In a situation of autarky (i.e., no trade), price-quantity equilibriums in each region are represented by points E_a and E_b Equilibrium prices and quantities are given by P_a and Q_a for region A, and P_b and Q_b for region B.

If trade is allowed between the two regions, equilibrium price, demand and supply quantities and trade flow will be determined by excess supply and demand relationships. ES_a represents excess supply for region A; that is, the amount by which domestic supply exceeds domestic demand at prices above the autarkic equilibrium (i.e., P_a). ED_b represents excess demand for region B; that is, the amount by which domestic demand exceeds domestic supply at prices below the autarkic equilibrium (i.e., P_b). In Figure 1, the excess demand for region B at price P_e is equal to Q_e, which is equal to the horizontal distance between D_b and S_b at that price. The excess supply for region A at price P_e is also equal to Q_e, which is equal to the horizontal distance between D_a and S_a at that price.

Given the relative demand and supply relationships in each region, the resulting trade flow is from A to B. Region A will provide excess supply to earn the higher outside price, which will in turn short the domestic market and drive the price in region A upward. Prices in region B will decrease because of lower priced supply that is available from region A. The new equilibrium price, P_e, is reached when the excess demand for region B equals the excess supply for region A.

In region A, the net results of trade with region B are increased price (i.e., from P_a to P_e), increased supply quantity (i.e., from Q_a to Q_a^S) and decreased demand quantity (i.e., from Q_a to Q_a^D). In region B, the net results of trade with region A are decreased price (i.e., from P_b to P_e), decreased supply quantity (i.e., from Q_b to Q_b^S) and increased demand quantity (i.e., from Q_b to Q_b^D).

As noted by Takayama and Judge (1971), the classic general equilibrium theory is indeed an idealized version of reality. Economists such as Graham (1946) and Samuelson (1952) have "extended" the theory to incorporate factors such as transfer costs (e.g., transportation cost, tariffs) and transactions costs (e.g., search costs). The scenario illustrated in Figure 1 can be extended to incorporate transfer costs, as illustrated in Figure 2.

In Figure 2, which represents the same two region single commodity situations as in Figure 1, the effective excess supply for region A is shifted "back" to ES^1_a. The vertical distance between ES^1_a and ES_a represents the transportation cost between regions A and B.

The net result of incorporating transportation costs is to reduce the equilibrium level of trade, relative to Figure 1 (i.e., from Q_e to Q_e'). The price in the excess demand region (i.e., B) differs from the price in the excess supply region (i.e., A) by an amount equal to the cost of transportation. Relative to the situation illustrated in Figure 1, the equilibrium price in region A is slightly lower and in region B is slightly higher.

This is illustrated Figure 2 (the notations in Figure 1 are the same for Figure 2). For example, when there is a transportation cost between Region A and B, the price received by Region A will be lower. Therefore, the excess supply from Region A will reduced. The equilibrium price in region A will change from P_a to P'_a as described in Figure 2. The reverse is also true for Region B, and the equilibrium price region B will change from P_b to P'_b. The difference between P'_a and P'_b will be equal to the transfer cost. Meanwhile, the equilibrium traded quantity will shrink from Q_e to Q'_e.

It is not difficult to extend this two-region scenario to a multi-region model by treating region B as a composite of all other trading regions in the market. Region A will trade with all the regions in the market. The reverse is also true if Region A is treated as a composite of other trading regions. Then Region B will trade with all the regions in the market.

Despite the productive efforts of many economists in specifying a conceptual framework in which space was explicitly introduced, the goal of capturing the corresponding "operational" model was not achieved until the work of Enke (1951) and Samuelson (1952). The framework for their empirical model is introduced and discussed later in this chapter.

4.1.1 Welfare Measures

Trade between two regions can be viewed as an attempt to increase social welfare. In order to assess gains or losses arising from trade and trade policy changes, economists must be able to measure social welfare for producers and consumers in the trading region.

In this study, a social welfare function (i.e., net social payoff) is defined and used to formulate a class of equilibrium problems within a mathematical programming format. The social welfare function is "simply a function of the utility levels of all individuals such that a higher value of the function is preferred to a lower one" (Just et al. 1982, p. 42). In order to evaluate the economic effects of trade liberalization, it is important to consider the benefits for both groups of participants; specifically, consumers and producers. Doing so requires an understanding of consumer and producer welfare measurement. In this study, these are represented as consumer surplus and producer surplus, respectively.

The economic concept of consumer surplus (CS) is based on the fact that consumers receive more utility from a commodity than is indicated by its market price; that is, they would be willing to pay more than the equilibrium price for the first unit consumed. In other words, before the last unit purchased, for which consumers' willingness to pay is equal to the market price, consumers enjoy economic surplus (i.e., the difference between willingness to pay and the actual market price). If the uncompensated or Marshallian demand curve is presented graphically by D(Q) in Figure 3, at price P_e (and corresponding quantity Q_e), CS is equal to area EP_eA.

If D(p) is the demand quantity for some good, expressed as a function of its price then the consumer surplus associated with price p^e is (Varian 1992):

(4.1-1) $$CS = -\int_{p^e}^{\infty} D(t)dt\,.$$

On the producer side, producer surplus (PS) (Marshall 1930) is used in the SPE model to measure the welfare of producers. Marshall (1930) first defined a producer's net benefit as the excess part of gross receipts, or the money a producer received for any commodities produced over their prime cost, and used the term "producer surplus" to refer to this benefit. Graphically, producer surplus is defined as the area above the supply curve and below the price line of the corresponding firm or industry (i.e., the area BEP_e in Figure 3). Just as the area under the demand curve measures the surplus enjoyed by the consumers of a good, the area above the supply curve measures the surplus (or sum of profit at each price or P_e in the figure) enjoyed by the suppliers of a good. If $S(p)$ is the supply quantity for some good, expressed as a function of its price then the producer surplus associated with price p^e is (Varian 1992):

(4.1-2) $$PS = \int_0^{p^e} S(t)dt\,.$$

Within the framework of an SPE, Samuelson (1952) defines a "Net Social Pay-off" (NSP) function as the sum of the social payoffs[13] in each region (i.e., spatial market) minus transportation costs. The social payoff in a particular region is defined as the algebraic area under its excess-demand curve and above its excess-supply curve (Samuelson 1952, p291). From the definition of consumer surplus and producer surplus, it is straightforward to see that the use of this area is consistent with welfare economics theory. In particular it represents the sum of consumers surplus and producer surplus.

The welfare effects of government-imposed market distortions such as production or marketing quotas can be considered using this framework. Figure 4 represents a demand-supply situation for some product within a particular region. Given demand (D) and supply (S), the initial equilibrium is at point E, resulting in quantity Q_e and price P_o. At this equilibrium point, consumer surplus is area of $a+d+f$, while producer surplus is area $b+c+e$. If a marketing quota q is imposed in this region such only quantity q can be

[13] Takayama and Judge (1971) use a "quasi-welfare function" to define the same measurement for the partial equilibrium situation.

marketed by producers, consumers will reduce consumption to *q* and pay a higher price, P_2. At this price, consumer surplus is now equal to the area f and the loss in consumer surplus is area *a* + *d*. Producers now produce and market quantity *q*, and receive price P_2. Producer surplus is now equal to area *a+b+c*. Therefore the net gain in producer surplus resulting from imposition of the quota is area *a-e*. The total social payoff in the region (i.e., consumer surplus and producer surplus) is reduced from area *a+b+c+d+e+f* to area *a+b+c+f*. There is a deadweight or net loss of social welfare (i.e., area *d+e*) which cannot be captured by either consumers or producers.

4.1.2 Uniqueness of Welfare Measurements for the SPE Model

Since Marshallian demand is relatively straightforward to estimate, consumer surplus has been the vehicle most often used in empirical work to measure consumer welfare (Just et al. 1982). However, it is argued by economists (e.g., Samuelson 1942) that, as a welfare measurement, consumer surplus is "not well defined. That is, consumer surplus is not generally a unique money measure for utility, and uniqueness can imply contradictions depending on the use of empirical data."(Just et al. 1982, p. 6).

Compensating variation and equivalent variation are two consumer welfare measures that are unique (Just et al. 1982). Compensating variation (CV) is the amount of money which, when taken away from an individual after an economic change, leaves the individual just as well off as before. Equivalent variation (EV) is the amount of money paid to an individual which, if an economic change does not happen, leaves the individual just as well off as if the change had occurred. If the information of willingness-to-pay for an individual is available, CV and EV will provide unique measurements of welfare change.

Figure 5 illustrates the three different welfare measures (i.e., CV, EV, and CS). In Figure 5, the compensated or Hicksian demand curve is presented by H(u_0) for initial price P_0 and H(u_1) after a price decrease to P_1. The CV associated with the price decrease is area *a*, or area P_0P_1FB. The EV is associated with this change is area *a+b+c* or area P_0P_1CE.

In Figure 5, the Marshallian demand for this individual is represented by $D(m_o)$. The corresponding change in consumer surplus (ΔCS) resulting from the price decrease is *a+b*, or area P_oP_1BC. As observed in Figure 5, the error of using *Δ*CS to measure the welfare change is area *b* or area *c* when compared with CV and EV, respectively. If areas b and c are negligible, then the change in consumer surplus may be used directly as an approximation of both the compensating and equivalent variations.

Mathematically, the relationship between Marshallian demand and Hicksian demand can be presented by the Slutsky equation (Varian 1992):

(4.1-3) $$\frac{\partial D(p,m)}{\partial p} = \frac{\partial H(p,U(p,m))}{\partial p} - \frac{\partial D(p,m)}{\partial m} D(p,m)$$

where *D(*)* is Marshallian demand, *H(*)* is Hicksian demand and *m* is total budget or income. The Slutsky equation decomposes the demand change induced by a price change into two separate parts: the price effect and the income effect. From this equation, the elasticity relationship between Marshallian demand and Hicksian demand can be derived through multiplication of both sides of the Slutsky equation by *p/x* (where *x* is the demand quantity):

(4.1-4) $$\varepsilon_h = \varepsilon_m - s\eta$$

where ε_m is the elasticity of the demand with respect to price, ε_h is the compensated elasticity holding income fixed, s is the expenditure share for the good in question (i.e., $p.x/m$), and η is the income elasticity of demand. The $s\eta$ term can be treated as the error term resulting from the use of consumer surplus as an approximate measure for CV or EV. If $s\eta$ is small relative to ε_m, then the effect of a price change for compensated demand can be reasonably throughout the use of Marshallian demand. In other words, in this situation consumer surplus is a reasonable welfare measure. Willig (1976) concludes that if the income elasticity or the total consumption share of that product is small for a given product is small, the error resulting from the use of consumer surplus as a welfare measurement is insignificant.

In the case of dairy products, the expenditure elasticity for fluid milk in Canada is relatively small (0.06) while the values for other dairy products range from 1.09 (for butter) to 1.46 (ice cream) (Veeman and Peng 1995). The share of dairy products in total consumer expenditure in Canada is small. For example, the average expenditure share of dairy product in total food expenditure per consumer in Canada was approximately 12.07% from 1986 to 1992 (Statistics Canada No. 15-511). The expenditure share for fluid milk was 4.5% for ice cream it was 1%, for cheese it was 2.9%, and for butter it was 0.86%.[14] Therefore, the likely errors from using consumer surplus as an approximate measure of welfare are 0.003% for table milk, 0.011% for butter, 0.038% for cheese and

[14]These estimates are based on retail prices (Veeman and Peng 1995), CPI (CANSIM), and per capita consumption for dairy products in Canada (Statistics Canada 1996b).

0.01% for ice cream. It should be noted that the income shares[15] of dairy products are likely to be much smaller than the expenditure shares. Therefore, consumer surplus is likely to be a reasonable approximation to CV or EV, when modeling welfare charge for dairy consumption.

Unlike the case for consumer surplus, changes in producer surplus resulting from a price change are identical to either the compensating variation or equivalent variation associated with that change (Just et al. 1982, Chapter 4). This is illustrated in Figure 6.

The producer in Figure 6 with supply (short-run marginal cost) curve S is faced with a price change from P_1, to P_2. Profit maximizing quantities for P_1 and P_2 are Q_1 and Q_2, respectively. The PS for price P_1 is the area *b* (i.e., the area above S and below P_1). The PS for price P_2 is the area *a+b* (i.e., the area above S and below P_2). Therefore the change in PS resulting from the price change is area *a*.

The compensating variation associated with this price increase is the sum of money that, when taken away from the producer, leaves her/him just as well off as if the price did not change. The change in profit resulting from the price change is area *a* (P_1P_2CD). This area is the compensating variation. Similarly, the equivalent variation associated with the price increase is the sum of money which, when given to the producer, leaves her/him just as well off without the price change as if the change had occurred. Since profit for P_1 is lower than at P_2 by the amount represented by area *a* (P_1P_2CD), this area must also represent the equivalent variation. The change in PS is identical to the CV or EV for a price change (Just et al. 1982).

[15] The income shares for dairy product expenditure are not readily available from the same source.

4.2 Spatial Price Equilibrium (SPE) Model

The model that concerns equilibrium among spatially separated markets was first developed from the linear programming transportation problem by Enke (1951). In the Enke problem, domestic demand and supply functions are given for a n-region market involving one commodity and are specified in terms of the market price in a particular location. Each region in the model is assumed to be separated from other region by exogenously determined per unit transportation costs (Takayama and Judge 1971). The objective associated with the basic SPE formulation aims to solve an inter-regional trade or spatial price equilibrium in such a way to maximize social welfare, where demand prices equal the sum of supply prices and transportation costs.

Samuelson (1952), starting from this spatial price equilibrium concept, was the first to derive a formal representation of the SPE problem as a linear programming model in which the total social welfare is maximized. Samuelson first defines a social welfare measurement - 'Net Social Pay-off'[16] (NSP) function as the sum of the consumer surplus and producer surplus in each region (spatial market) minus the transport cost. The spatial equilibrium problem is solved by using excess demand and supply functions for the various inter-regional markets, as defined in previous section. Using excess-supply function ES_a for region A, excess-demand function ED_b for region B, unit transportation costs t_{ab} and letting Q_e denote the exports from region A to region B, then the NSP is as follows (Samuelson 1952):

(4.2-1)
$$NSP = \int_0^{Q_e} ED_b(x)dx - \int_0^{Q_e} ES_a(x)dx - t_{ab}.Q_e$$

Since the first SPE model was developed by Samuelson (1952), a proliferation of theoretical advances have improved and extended the basic linear programming transportation and spatial equilibrium models. Takayama and Judge (1964) reformulated Samuelson's NSP model into an operationally efficient concave quadratic programming (QP) model. Several modifications of the basic single-price, static equilibrium QP modeling approach were made in the 1970s. Takayama and Liu (1975) constructed a world wheat trade model that not only optimized across space but also simultaneously through time. Chavas et al. (1993), use a hedonic pricing model (i.e., modeling the demand and supply of milk components instead of milk itself) to analyze resource allocation in the U.S. dairy sector. While not all trade studies use the QP modeling approach it still represents the most commonly used form (Bergh et al. 1996).

In a more general scenario involving multiple commodities and multiple regions, an aggregate Net Social Payoff function is obtained by summing the NSP functions across commodities and across regions, and subtracting the costs of inter-regional transportation. Following Takayama and Judge's (1971) framework, the aggregated net social payoff function (or quasi-welfare function) is maximized subject to demand and supply restriction, as follows:

(4.2-2a) $$NSP = \sum_{n.j} \int_0^{D_{n.j}} P^d_{n.j}(x)dx - \sum_{n.i} \int_0^{S_{n.i}} P^s_{n.i}(y)dy - \sum_{n.i.j} X_{n.i.j} \cdot t_{n.i.j}$$

subject to:

(4.2-2b) $$S_{n,i} \geq \sum_j X_{n,i,j} \quad \forall n, \ \forall i,$$

[16] The social payoff in a region is defined as the algebraic area under the excess-demand curve or above the excess-supply curve (Samuelson 1952, p291).

(4.2-2c) $\sum_i X_{i,n,j} \geq D_{n,j} \quad \forall n, \forall j$

$S_{n,i} \geq 0,\ X_{n,i,j} \geq 0,\ D_{n,j} \geq 0$

where

$P^s_{n,i}(S_{n,i})$ = Quantity dependent supply for the n-th commodity in region i,

n = 1,...,N and i = 1,...,I;

$P^d_{n,j}(D_{n,j})$ =Quantity dependent demand for the n-th commodity in region j,

n =1,...,N and j = 1, . . . J;

$S_{n,i}$ = quantity supplied production of the n-th commodity in region i, n = 1,...,N and i = 1,...,I;

$D_{n,j}$ = quantity demanded of the n-th commodity in region j, n =1,...,N and j = 1, . . . J;

$X_{n,i,j}$ = exports of the n-th final commodity from region i to region j, n = 1,...,N, i = 1,...,I and j= 1,...,J;

$t_{n,i,j}$ = unit transportation cost of exporting the n-th final commodity from region i to region j, n = 1,...,N, i = 1,...,I and j = 1,...,J;

Constraint *(4.2-2b)* states that for any final commodity n in region i, shipments from that region (including shipment to region i) cannot exceed the supply quantity. Constraint *(4.2-2c)* states that for any final commodity n in region j, the total demand cannot exceed shipments to that region (including shipment from region j). The Lagrangian function (L) for this constrained maximization problem can be expressed as follows:

(4.2-2c) $$L = \sum_{n,j}\int_0^{D_{n,j}} P^d_{n,j}(x)dx - \sum_{n,i}\int_0^{S_{n,i}} P^s_{n,i}(y)dy - \sum_{n,i,j} X_{n,i,j}.t_{n,i,j}$$

$$+ \sum_{n,i} \alpha_{n,i} (S_{n,i} - \sum_j X_{j,n,i}) + \sum_{n,j} \beta_{n,j} (\sum_i X_{i,n,j} - D_{n,j})$$

where $\alpha_{n,i}$ and $\beta_{n,j}$ are non-negative Lagrangian multipliers corresponding to the two sets of constraints. The Kuhn-Tucker conditions associated with the optimization problem provide the following necessary and sufficient conditions for the solution to the model:

(4.2-3a) $$\partial L/\partial S_{n,i} = -P^S{}_{n,i}(S_{n,i}) + \alpha_{n,i} \leq 0, \; S_{n,i} \geq 0$$

$$\text{and } (\partial L/\partial S_{n,i})\, S_{n,i} = 0 \qquad \forall n, \forall i$$

(4.2-3b) $$\partial L/\partial D_{n,j} = P^d{}_{n,j}(D_{n,j}) - \beta_{n,j} \leq 0, \; D_{n,j} \geq 0$$

$$\text{and } (\partial L/\partial D_{n,j})\, D_{n,j} = 0, \qquad \forall n, \forall j$$

(4.2-3c) $$\partial L/\partial X_{n,i,j} = -\alpha_{n,i} + \beta_{n,j} - t_{n,i,j} \leq 0, \; X_{n,i,j} \geq 0$$

$$\text{and } (\partial L/\partial X_{n,i,j})\, X_{n,i,j} = 0, \qquad \forall n, \forall i, \forall j$$

(4.2-3d) $$\partial L/\partial \alpha_{n,i} = S_{n,i} - \sum_j X_{j,n,i} \geq 0, \; \alpha_{n,i} \geq 0$$

$$\text{and } (\partial L/\partial \alpha_{n,i})\, \alpha_{n,i} = 0 \qquad \forall n, \forall i$$

(4.2-3e) $$\partial L/\partial \beta_{n,j} = \sum_i X_{n,i,j} - D_{n,j} \geq 0, \; \beta_{n,j} \geq 0$$

$$\text{and } (\partial L/\partial \beta_{n,j})\, \beta_{n,j} = 0 \qquad \forall n, \forall j$$

The Lagrangian multipliers $\alpha_{n,i}$ and $\beta_{n,j}$ are the shadow prices for the trade constraints (*4.2-2b* and *4.2-2c*). More specifically, $\alpha_{n,i}$ is the supply price for one unit of product $S_{n,i}$ whenever $S_{n,i}$ is positive. In condition (*4.2-3*b) $\beta_{n,j}$ is the demand price for product $D_{n,j}$ whenever $D_{n,j}$ is positive.

Conditions (*4.2-3*d) and (*4.2-3*e), together with the complementary slackness conditions with respect to the corresponding Lagrange multipliers, simply restate the original trade flow constraints *(4.2-2b* and *4.2-2c)*. They represent the feasibility conditions for interregional trade.

Condition (*4.2-3*c) characterizes the transportation arbitrage conditions expressed in terms of spatial prices. This condition states that commodity prices in the importing region and the exporting region cannot differ by more than the corresponding unit transportation cost ($t_{n,i,j}$). In the cases where trade takes place (i.e., $X_{n,i,j}>0$, for $i \neq j$), the spatial price difference between the importing region and the exporting region must be equal to the unit transportation cost.

4.3 Extension of the Basic SPE Model for the Canadian Dairy Industry

Although the SPE model presented above has been used widely by many economists to analyze inter-regional trade, the above basic SPE needs to be "extended" in order to use it to model the Canadian dairy sector. This is due to the multi-level nature of dairy industry and the presence of supply management.

4.3.1 A Multi-level SPE Model

In the basic SPE model, both production and consumption are in a single "level", so that the commodities produced by producers are the commodities consumed by consumers. There are no primary or intermediate products, so that all products are final products. However, the dairy industry has at least two levels of production, intermediate commodities (i.e., raw milk) and final commodities (i.e., processed dairy products).[17] Final dairy products require raw milk, as well as the services of a processing and handling industry. The intermediate commodities are not consumer goods but are used exclusively as inputs in the production of the secondary commodities. Dairy farming- and dairy-processing are two vertically related sectors.

Based on the theoretical framework of trade equilibrium, it is possible to extend the basic single level SPE model to incorporate multi-level production including both intermediate and final products. As discussed by Houck (1986), the vertical market structure can be expressed as in Figure 7. If it is assumed that the production relationship between the intermediate product (e.g., raw milk) and processing inputs (e.g., labor, energy) is to combine the milk input and other inputs in fixed proportions to produce one unit of the final dairy product, then the supply curve for the final product can be treated as the aggregate of the supply curves for raw milk and processing inputs.

In Figure 7, diagram (a) represents the supply (SR) of raw milk (i.e., the dairy farming sector). Diagram (b) represents the supply all other inputs (i.e., the processing sector). The implied supply function for the final product (i.e., processed dairy products) is SF and the final demand function is DF, both of which are presented in diagram (c). This final supply function is derived from supply functions for the intermediate inputs (i.e., raw milk and other processing inputs).

[17] Furthermore, in the Canadian dairy industry, one of important inputs for milk production is the feed (e.g., barley, corn, hay, pasture), which is the product of another agricultural sector (i.e., the cropping sector). If the dairy model is to have reasonable inter-linkages to other agricultural sectors, then some products of the crop sector will be primary products and the milk will be an intermediate product.

This three panel vertical market diagram can be extended to incorporate more vertical market levels and a more aggregated model. If the raw milk sector (a) is treated as another intermediate product and crop production is treated as a primary input, then this simple model is extended to three vertical market levels which incorporate the linkage between the dairy industry and the crop sector. Although there is no explicit intermediate demand curve include in this framework, any change in intermediate supply is implicitly reflected in the final demand and supply relationship. Therefore, by extending the basic SPE model to this vertical market framework, it is possible to analyze the policy impacts for different sectors of the Canadian dairy industry.

This vertical market structure is captured in the objective function by replacing the supply $P^{S}_{n,i}(y)$ for the final dairy product $S_{n,i}$ with the producer surplus for each market level for the product: $P^{S1}_{m,i}(y)$ for the m intermediate products $S_{m,i}$ (where m=1 for fluid milk and m=2 for industrial milk) and $P^{S2}_{n,i}(y)$ for the n final products $S_{n,I}$, as follow:

(4.3-1) $$\sum_{n,i}\int_0^{S_{n,i}} P^{S}_{n,i}(y)dy = \sum_{m,i}\int_0^{S_{m,i}} P^{S1}_{m,i}(y)dy + \sum_{n,i}\int_0^{S_{n,i}} P^{S2}_{n,i}(y)dy$$

where

$P^{S1}_{m,i}$ = price dependent supply function (of quantities) for raw milk product m, in region i, m=1,2, i = 1,...,I;

$P^{S2}_{n,i}$ = price-dependent supply function (of quantities) for the n-th final product in region i, n = I,...,N and i = 1,...,I.

$S_{m,i}$ = production of the m-th intermediate commodity in region i, m = 1, 2 and i = 1,...,I;

$S_{n,i}$ = production of the n-th final product in region i, n = 1,...,N and i = 1,...,I;

The transportation cost should also be extended in the multi-level model by including transportation costs for primary products:

$$X_{m,i,j} . t_{m,i,j}$$

where

$X_{m,i,j}$ = exports of raw milk product m from region i to region j, m=1, 2, i = 1,...,I and j= 1,...,J;

$t_{m,i,j}$ = unit cost of transportation for raw milk from region i to region j, determined exogenously, m=1,2, i = 1,...,I and j = 1,...,J;

4.3.2 A Hedonic SPE Model

In the dairy-processing industry, the inputs for secondary commodities are not raw milk but the components of raw milk: butterfat and solids-not-fat (SNF), which include protein, carbohydrates, and other non-fat components. Therefore, the allocation of these milk components among secondary commodities across space is of interest. However, this aspect of the dairy industry has not drawn the attention of many researchers to date. For example, the studies by Ewasechko and Horbulyk (1995), Mussell (1993) and Rude (1992) do not address this consideration. Although CRAM does incorporate milk components, this characteristic has not been explicitly addressed in available documentation.

Use of a hedonic technique is appropriate when the "goods" are characteristics reflecting quality differences. The hedonic issue was addressed by Gorman (1956) when studying household utility from non-market goods. Hedonic theory was further advanced by Becker (1965) and Lancaster (1966). In a hedonic model the demand for a product or input is considered to be a function of its characteristics. Given the natural demand for milk component by processor, an economic model that expresses milk value as a function of milk characteristics would be appropriate for use here.

In general, a hedonic model will be able to deal with the product attributes and their value. For example, in the case of a dairy processor producing a dairy product, *m*, a production function may be defined as follows:

$$(4.3\text{-}2) \qquad m = f(x),$$

where x is an S-vector of input characteristics. If the "value" of m is based more on the value of the characteristics (x) instead of on the whole final product, then it make sense to explicitly address the characteristics x in an empirical model of demand.

In the context of the SPE model, assume that the *M* intermediate commodities involve *S* characteristics, the *s*-th characteristics being denoted by r_s, $s= 1,\dots,S$. Each intermediate and secondary commodity in each region has a given composition in terms of its underlying characteristics. Assume $a_{j,m,s} \geq 0$ represent the quantity of the *s*-th characteristic (where *s*=1 for the butterfat component and *s*=2 for SNF in raw milk) per unit of *m*-th intermediate commodity $D_{m,j}$ demanded in region j (i.e., fluid milk and industrial milk used as inputs for processed products). Let $b_{i,n,s} \geq 0$ denote the quantity of the *s*-th characteristic required per unit of supply for the n-th secondary commodity $S_{n,i}$ (e.g., table milk, butter, cheese). In order to ensure balance for hedonic component *s* in each region, the following constraint for hedonic components is added to the model:

(4.3-3) $$\sum_m D_{m,j}\, a_{j,m,s} \geq \sum_n S_{n,i}\, b_{i,n,s} \text{ (where } i=j)$$

This constraint explicitly addresses the balance of dairy components; that is, the total usage of dairy product component in a given area cannot exceed the total supply of this component. This constraint could also be considered as the "transformation" constraint that represents technology in the model (i.e., converting raw milk components into processed products).

4.3.3 An SPE Model Incorporating Government Intervention

In an industry with marketing quotas, more constraints are required in the SPE model to reflect this government intervention. In the model, assume that $Q_{i,m}$ is the quota for the m-th primary commodity (where $Q_{i,1}$ is fluid milk quota and $Q_{i,2}$ is industrial quota associated with fluid milk production $S_{i,1}$ and industrial milk is $S_{i,2}$, respectively) in each region i. The following quota constraint is added to the model:

(4.3-4) $$S_{i,m} \leq Q_{i,m}$$

In order to incorporate possible policy changes in the dairy sector, it is also necessary to consider the possibility of inter-regional transfer for milk quota and milk. If quota trading is allowed, the direction and magnitude of transfer between regions will depend on the static quota value in each region. Figure 8, taken from Mussell and Godded (1996), illustrates the effects of milk and milk quota transferability. Prior to trade, the milk quota in regions *A* and *B* are Q_{a0} and Q_{b0}, respectively. Given demand and supply relationships, the price received by producers in region *A* is P_{a0}, while the marginal cost of milk production is MC_{a0} (similarly for region B). The difference between P_{a0} and MC_{a0} (or P_{b0} and MC_{b0})is the rental value of quota.

In order to simplify the situation, assume initially that only quota for raw milk be traded. The region with the higher quota value (i.e., region A) will tend to bid quota away from the region with the lower quota price (i.e., region B). The quota price will decrease in region A since it has gained quota, and the quota price in region B will increase since it has lost quota. If only the quota is allowed to transfer, equilibrium will be achieved when the quota prices are equal in both regions; that is $P_{a1}MC_{a1}$ in region A is equal to $P_{b1}MC_{b1}$ in region B.

If allowed, it is also possible that raw milk will transfer since there is price difference between region *A* and *B* (i.e., P_{b1}-P_{a1}). However, whether milk actually transfers between regions will depend on the transaction costs such as transportation cost between region *A* and *B*, or the cost of acquiring the necessary quota. If the unit cost is lower than $P_{b1} . P_{a1}$, then raw milk will move between region *A* and *B*. This framework can be applied in the current study to extend the model to allow the movement of milk or quota among regions. The quota constraint can be expressed as:

$$(4.3\text{-}5) \qquad S_{i,m} \leq Q_{i,m} + \sum_j Q_{j,i,m}$$

where $Q_{j,i,m}$ is the "extra" quota transferred into or out of region *i* and $S_{i,m}$ and $Q_{i,n}$ are defined as before. This constraint states that after the transfer of the milk marketing quota, the total amount of milk production in a given region cannot exceed the original quota plus any quota it gained or lost.

The involvement of government in the dairy industry includes the control of quantities as well as the price. Any government subsidies or levies are incorporated as part of the producer surplus calculated in the objective function.

4.4 An SPE Model With Hedonic Characteristics for a Regulated Vertical Market

After extending the basic SPE model as discussed in the previous section, the following model with hedonic characteristics for a regulated vertical market is used in the current study. The quasi-welfare function optimization problem can be summarized as:

(4.4-1a)

$$Max: \sum_{n,j} \int_0^{D_{n,j}} P^d_{n,j}(x)dx - (\sum_{m,i} \int_0^{S_{m,i}} P^{S1}_{m,i}(y)dy + \sum_{n,i} \int_0^{S_{n,i}} P^{S2}_{n,i}(y)dy)$$
$$- \sum_{m,i,j} X_{m,i,j} t_{m,i,j} - \sum_{n,i,j} X_{n,i,j} t_{n,i,j}$$

subject to

(4.4-1b) $$S_{m,i} \geq \sum_j X_{j,m,i,} \ \forall m, \ \forall i,$$

(4.4-1c) $$\sum_i X_{i,m,j} \geq D_{m,j}, \ \forall m, \ \forall j$$

(4.4-1d) $$S_{n,i} \geq \sum j \, X_{j,n,i,} \ \forall n, \ \forall i,$$

(4.4-1e) $$\sum_i X_{i,n,j} \geq D_{n,j} \ \forall n, \ \forall j$$

(4.4-1f) $$\sum_m D_{m,j} \, a_{j,m,s} \geq \sum_n S_{n,i} \, b_{n,i,s}, \ \forall \text{i=j} \ \forall s$$

(4.4-1g) $$Q_{m,i} \geq S_{m,i,} \ \forall m, \ \forall i,$$

$$S_{m,i} \geq 0, D_{m,j} \geq 0, S_{n,i} \geq 0, D_{n,j} \geq 0, D_{m,j} \geq 0, X_{j,m,i,} \geq 0, X_{n,i,j} \geq 0$$

with the corresponding Lagrangian:

$$L = \sum_{n,j} \int_0^{D_{n,j}} P_{n,j}^d(x)dx - (\sum_{m,i} \int_0^{S_{m,i}} P_{m,i}^{S1}(y)dy + \sum_{n,i} \int_0^{S_{n,i}} P_{n,i}^{S2}(y)dy)$$

$$- \sum_{m,i,j} X_{m,i,j} t_{m,i,j} - \sum_{n,i,j} X_{n,i,j} t_{n,i,j}$$

$$+ \sum_{m,i} \alpha_{m,i} (S_{m,i} - \sum_j X_{j,m,i})$$

$$+ \sum_{m,j} \beta_{m,j} (\sum_i X_{i,m,j} - D_{m,j})$$

$$+ \sum_{n,i} \gamma_{n,i} (S_{n,i} - \sum_j X_{j,n,i})$$

$$+ \sum_{n,j} \delta_{n,i} (\sum_i X_{i,n,j} - D_{n,j})$$

$$+ \sum_{s,i} \lambda_{s,i} (\sum_m D_{m,i}\, a_{m,i,s} - \sum_n S_{n,i}\, b_{n,i,s})$$

$$+ \sum_{m,i} \theta_{m,i} (Q_{m,i} - S_{m,i})$$

where

i =	production region for intermediate product *m* or final product *n*
j =	demand region for intermediate product *m* or final product *n*
$P^d{}_{n,j}(D_{n,j})$ =	Quantity dependent demand for the n-th commodity in region j, n =1,...,N and j = 1, . . . J;
$P^{S1}{}_{m,i,}(S_{m,i})$ =	Quantity dependent supply function for raw milk product *m*, *m*=1,2 in region i, i = 1,...,I;
$P^{S2}{}_{n,i}(S_{n,i})$ =	Quantity dependent supply function for the n-th intermediate commodity in region i, n = I,...,N and i = 1,...,I.

$S_{m,i}$ = production of the m-th intermediate commodity in region i, m = 1,...,M and i = 1,...,I;

$S_{n,i}$ = production of the n-th final commodity in region i, n = 1,...,N and i = 1,...,I;

$D_{n,j}$ = consumption of the n-th final commodity in region j, n = 1,...,N and j = 1, . . . J;

$X_{n,i,j}$ = exports of the n-th final commodity from region i to region j, n = 1,...,N, i = 1,...,I and j= 1,...,J;

$X_{m,i,j}$ = exports of the m-th raw milk commodity from region i to region j, m = 1,...,M ,i = 1,...,I and j= 1,...,J;

$D_{m,j}$ = intermediate commodity of the m-th raw milk from in region j, m = 1,...,M and j= 1,...,J;

$t_{m,i,j}$ = cost of transportation for the raw milk production from region i to region j, m = 1,...,M, i = 1,...,I and j = 1,...,J;

$t_{n,i,j}$ = unit transportation cost of the n-th final commodity from region i to region j, n = 1,...,N, i = 1,...,I and j = 1,...,J;

$a_{j,m,s}$ = hedonic raw milk component supplied of the *s*-th characteristic per unit of m-th intermediate commodity, m = 1,...,M, s = 1,...,S and j = 1,...,J;

$b_{i,n,s}$ = hedonic component requirement for the *s*-th characteristic per unit of n-th final commodity, n = 1,...,N, s = 1,...,S and j = 1,...,J;

$Q_{i,m}$ = quota constraints for the m-th intermediate commodity in region i. m = 1,...,M, i = 1,...,I and j = 1,...,J;

$\alpha_{m,i}$, $\beta_{m,i}$, $\gamma_{n,i}$, $\delta_{n,i}$, $\lambda_{s,i}$ and $\theta_{m,i}$ are non-negative Lagrangian multipliers corresponding to the various constraints. The Kuhn-Tucker conditions associated with the optimization problem provide necessary and sufficient conditions for the solution of the model. They are:

(4.4-2a) $\partial L/\partial S_{m,i} = -P^{S1}{}_{m,i}(S_{m,i}) + \alpha_{m,i} - \theta_{m,i} \leq 0,\ S_{m,j} \geq 0$

$\text{and } S_{m,i}(\partial L/\partial S_{i,m}) = 0, \qquad \forall m$

(4.4-2b) $\partial L/\partial S_{n,i} = -P^{S2}{}_{n,i}(S_{n,i}) + \gamma_{n,i} - \sum_s \lambda_{s,i}\, b_{s,i,n} \leq 0,\ S_{n,i} \geq 0$

$\text{and } (\partial L/\partial S_{i,n})\, S_{i,n} = 0 \qquad \forall n,\ \forall i$

(4.4-2c) $\partial L/\partial D_{m,j} = \partial L/\partial D_{m,i} = -\beta_{m,j} + \sum_s \lambda_{s,i}\, a_{s,m,i} \leq 0,\ D_{m,j} \geq 0$

$\text{and } (\partial L/\partial D_{m,j})\, D_{m,j} = 0, \qquad \forall,\ i = j\ \forall m$

(4.4-2d) $\partial L/\partial D_{n,j} = P^{d}{}_{n,j}(D_{n,j}) - \delta_{n,i} \leq 0,\ D_{n,j} \geq 0$

$\text{and } (\partial L/\partial D_{n,j})\, D_{n,j} = 0, \qquad \forall n,\ \forall j$

(4.4-2e) $\partial L/\partial X_{m,i,j} = -t_{m,i,j} - \alpha_{m,i} + \beta_{m,i} \leq 0,\ X_{m,i,j} \geq 0$

$\text{and } X_{m,i,j}(\partial L/\partial X_{m,i,j}) = 0, \qquad \forall m, \forall i, \forall j$

(4.4-2f) $\partial L/\partial X_{n,i,j} = -t_{n,i,j} - \gamma_{n,i} + \delta_{n,i} \leq 0,\ X_{n,i,j} \geq 0$

$\text{and } (\partial L/\partial X_{n,i,j})\, X_{n,i,j} = 0, \qquad \forall n,\ \forall i, \forall j$

(4.4-2g) $\partial L/\partial \alpha_{m,i} = S_{m,i} - \sum_j X_{j,m,i} \geq 0,$

$\text{and } \alpha_{m,i}(\partial L/\partial \alpha_{m,i}) = 0, \qquad \forall m, \forall i$

(4.4-2h) $\partial L/\partial \beta_{m,i} = \sum_i X_{i,m,j} - D_{m,i} \geq 0,$

$$and\ \beta_{m,i}(\partial L/\partial \beta_{m,i}) = 0, \qquad \forall m, \forall j$$

(4.4-2h) $$\partial L/\partial \gamma_{n,i} = S_{n,i} - \sum_j X_{j,n,i} \geq 0,$$

$$and\ \gamma_{n,i}(\partial L/\partial \gamma_{n,i}) = 0, \qquad \forall n, \forall j$$

(4.4-2i) $$\partial L/\partial \delta_{n,i} = \sum_i X_{i,n,j} - D_{n,j} \geq 0,$$

$$and\ \delta_{n,i}(\partial L/\partial \delta_{n,i}) = 0, \qquad \forall n, \forall j$$

(4.4-2j) $$\partial L/\partial \lambda_{s,i} = \sum_m D_{m,i}\, a_{m,i,s} - \sum_n S_{n,i}\, b_{n,i,s} \geq 0,$$

$$and\ \lambda_{s,i}(\partial L/\partial \lambda_{s,i}) = 0, \qquad \forall\ i=j$$

(4.4-2k) $$\partial L/\partial \theta_{m,i} = Q_{m,i} - S_{m,i} \geq 0,$$

$$and\ \theta_{m,i}(\partial L/\partial \theta_{m,i}) = 0, \qquad \forall m, \forall i, \forall j$$

Without the quota restriction, $\alpha_{m,i}$ can be interpreted as the market price for primary commodity $S_{m,i}$ in region i, as shown in condition (4.4-2*a*). $\theta_{m,i}$ is the shadow value of marketing quota $Q_{m,i}$ for the m-th intermediate product. Condition (4.4-2*a*) states that, at the optimal solution, the sum of the market price for intermediate product $S_{m,i}$ and the shadow value of the marketing quota is equal to the supply price of the intermediate commodity, whenever $S_{m,i}$ is positive.

In condition (4.4-2*b*) $\lambda_{s,i}$ can be interpreted as the shadow price of the s-th component of products in region i. Condition (4.4-2*b*) involves the marginal cost of the n-th secondary product $S_{n,i}$, and the marginal cost of the *s* components ($\sum_s \lambda_{s,i}\, b_{s,i,n} \geq 0$). At the optimal solution, the shadow value ($\gamma_{n,i}$) of the final commodity $S_{n,i}$ is equal to the sum of the market price of the final product plus the shadow value of the *s* components.

Condition (4.4-2*c*) involves the market value of the m-th intermediate product $D_{m,i}$, and the marginal cost of the *s* components ($\sum_s \lambda_{s,i}\, a_{s,i,m}$). At the optimal solution, the shadow value (i.e., $\beta_{m,j}$) of the intermediate product $D_{m,i}$ is equal to the sum of the shadow value of the *s* components for this product.

Similarly, it follows from condition (4.4-2d) that the shadow value $\delta_{n,i}$ can be interpreted as the marginal cost (or marginal value) of the secondary commodity $D_{n,j}$ in region *i*. Condition (4.4-2d) states that, at the optimal solution, the supply value of the final commodity $S_{n,i}$ is equal to its demand price whenever $S_{n,i}$ is positive.

Conditions (4.4-2e) and (4.4-2f) characterize the transportation arbitrage conditions expressed in terms of spatial prices. These two conditions state that commodity prices between the importing region and the exporting region cannot differ by more than the corresponding unit transportation cost. In the case where trade takes place (i.e., $X_{m,i,j} > 0$ or $X_{n,i,j} > 0$, for $i \neq j$) then the spatial price difference between the importing region and the exporting region must be exactly equal to the unit transportation cost.

Conditions (4.4-2g), (4.4-2h), (4.4-2*h*) and (4.4-2*i*), together with the complementary slackness conditions with respect to the corresponding Lagrangian multipliers, are the trade flow constraints. They represent the feasibility conditions for interregional trade.

4.5 Assumptions and limitation of SPE models

Several simplifying assumptions need to be made in order to make use of SPE models. Dairy farmer and processing firms are assumed to be profit maximizing, consumers are assumed to be utility maximizing, supply and demand regions are represented by a single fixed point and regional demand and supply are represented by a linear function. These linear demand and supply functions are necessary to generate a quadratic welfare measurement in the objective function. Final dairy products are assumed to be homogeneous, and consumers are indifferent to the supply source. Price is the only factor assumed to influence regional consumption. These assumptions are necessary in order to specify the model, and as a result, may limit its applicability.

One problem associated with spatial equilibrium analysis is the aggregation assumption. This problem arises from the assumption of regions being represented by a single point (i.e., each province) rather than a continuum of points. The error resulting from this problem can be minimized by increasing the number of regions (i.e., disaggregation) if each representative point is broken down to more sub - representative. Since the objective of this study is to analyze the economic impacts of policy interventions for the dairy industry, a partial equilibrium analysis approach is applied. A more general approach may be the general equilibrium model that includes all domestic macroeconomic and other economic factors. It is argued by Houck (1986) that partial equilibrium analysis is the most useful approach for assessing immediate economic impacts. However, it limits the empirical results to a specific sector of the domestic economy and other economic factors have to be taken as being constant. In the current study, a disadvantage of this approach is that it suppresses interactions between the dairy sector and other agricultural or industrial sectors. This weakness is overcome, however, by using a model that incorporates not only the sector of direct interest (i.e., the dairy sector) but also other relevant agricultural markets and production sectors (e.g., beef and crops).

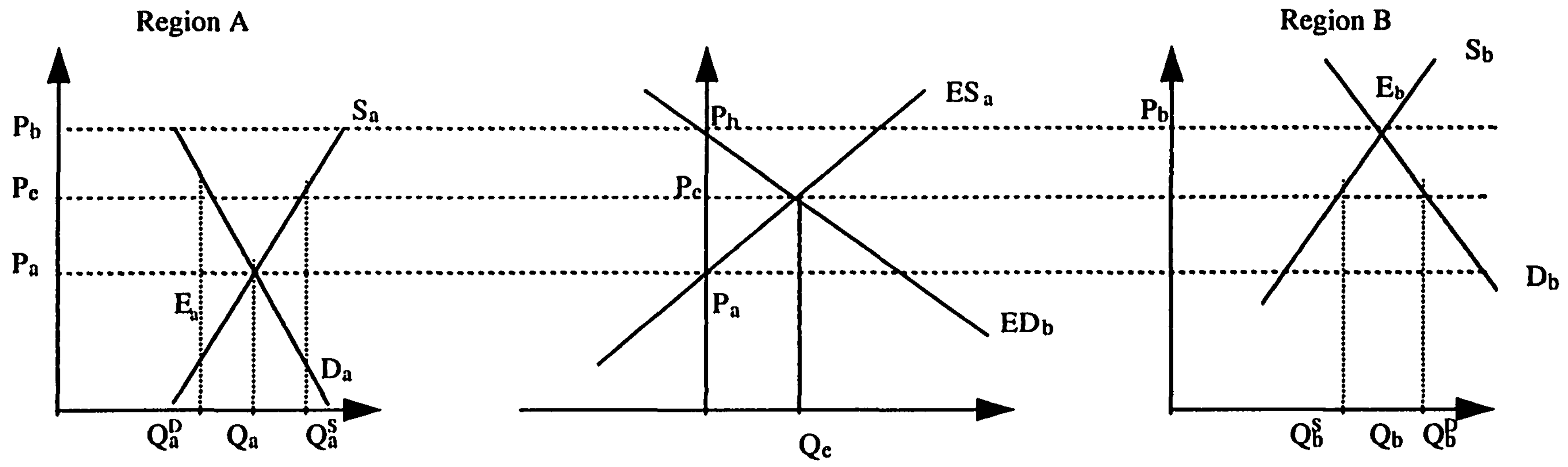

Figure 1: Graphical Representation of a Two Region One Commodity Spatial Equilibrium

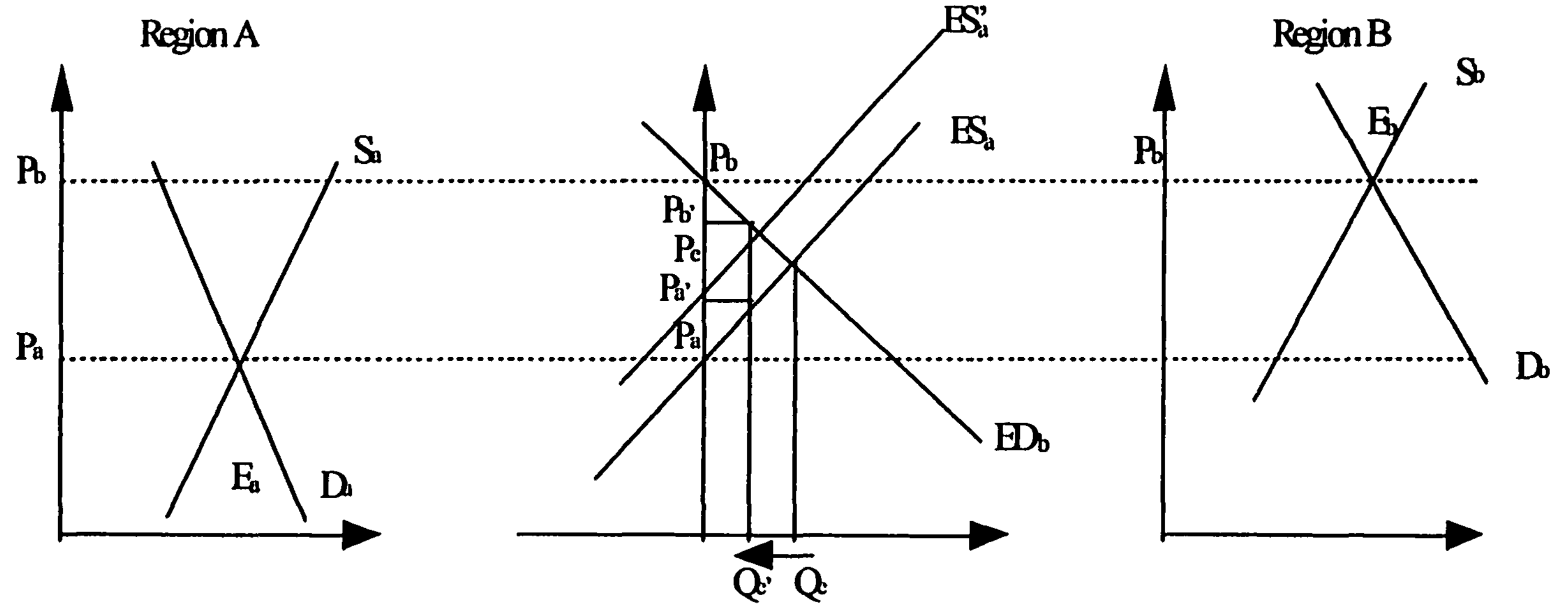

Figure 2: Diagram Spatial Equilibrium with Transportation cost

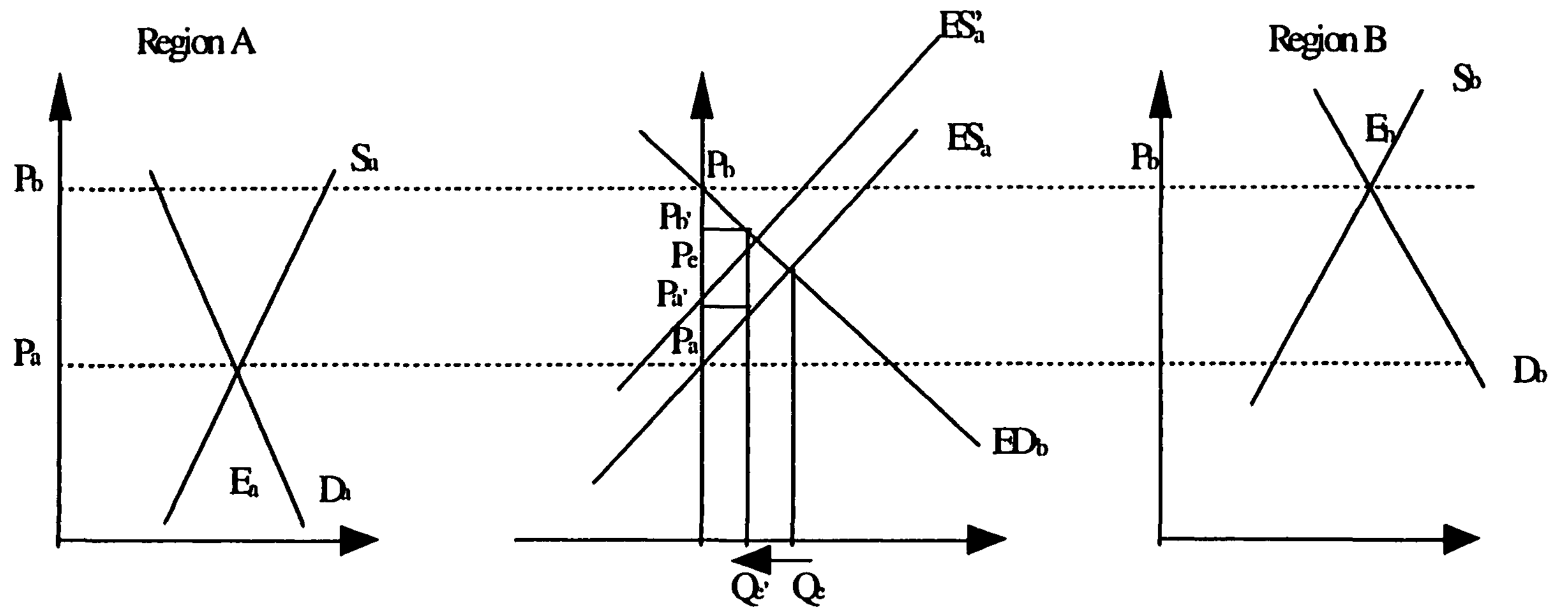

Figure 2: Diagram Spatial Equilibrium with Transportation cost

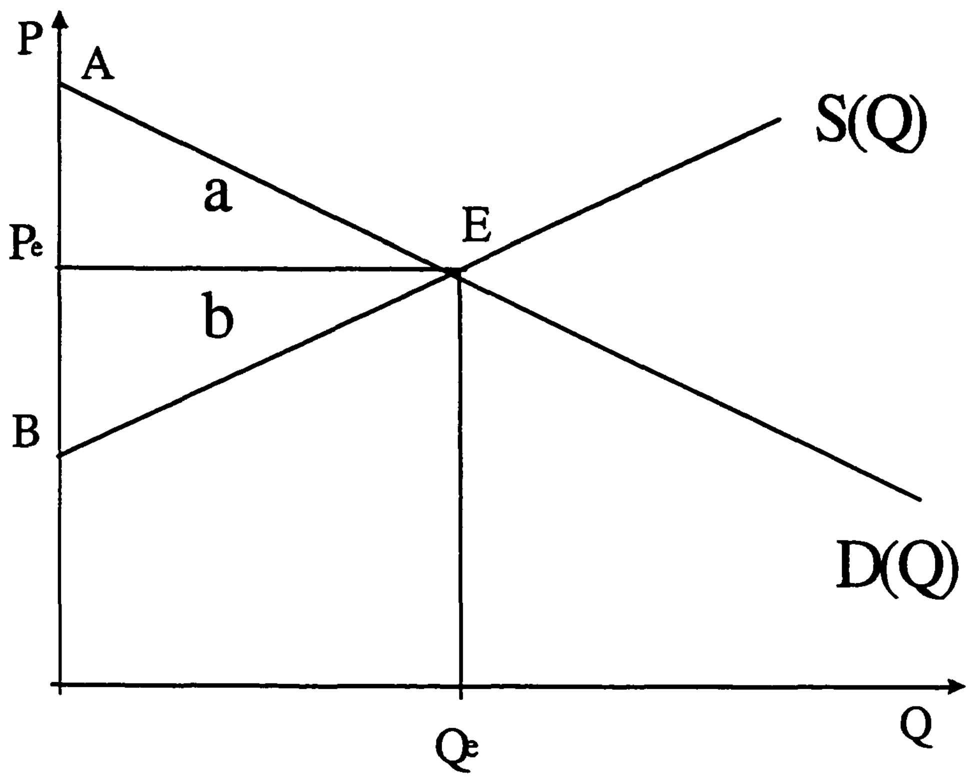

Figure 3. Social Welfare Measurement

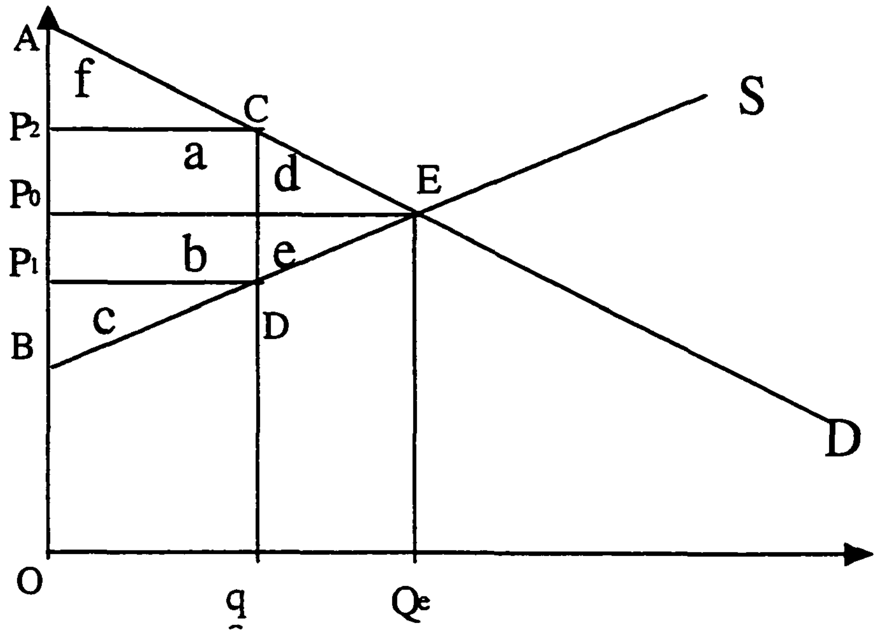

Figure 4. Social Welfare Effects of a Marketing Quota

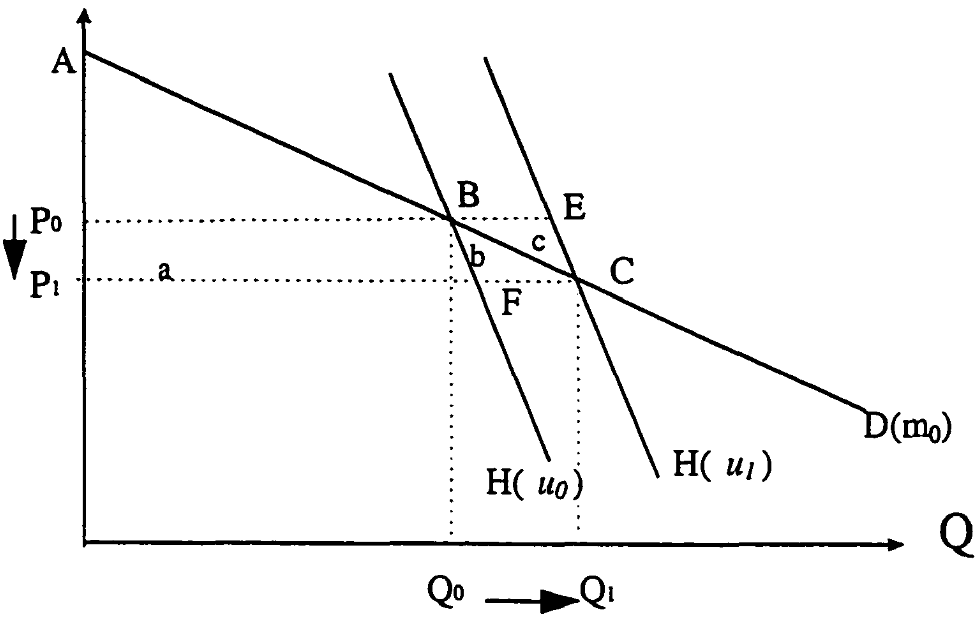

Figure 5. Compensated Variation and Equivalent Variation and Consumer Surplus

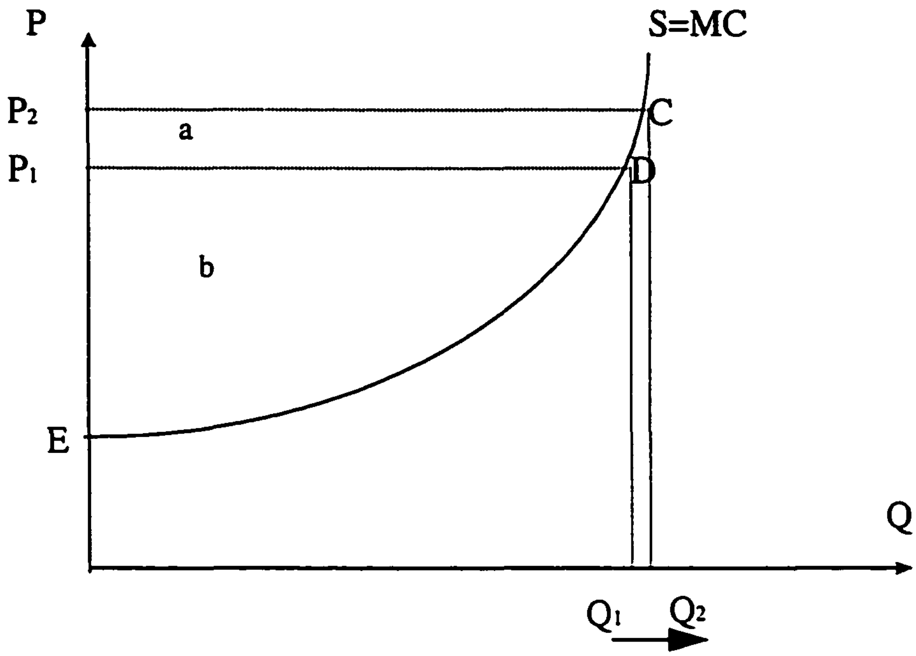

Figure 6. Producer Welfare Measurement

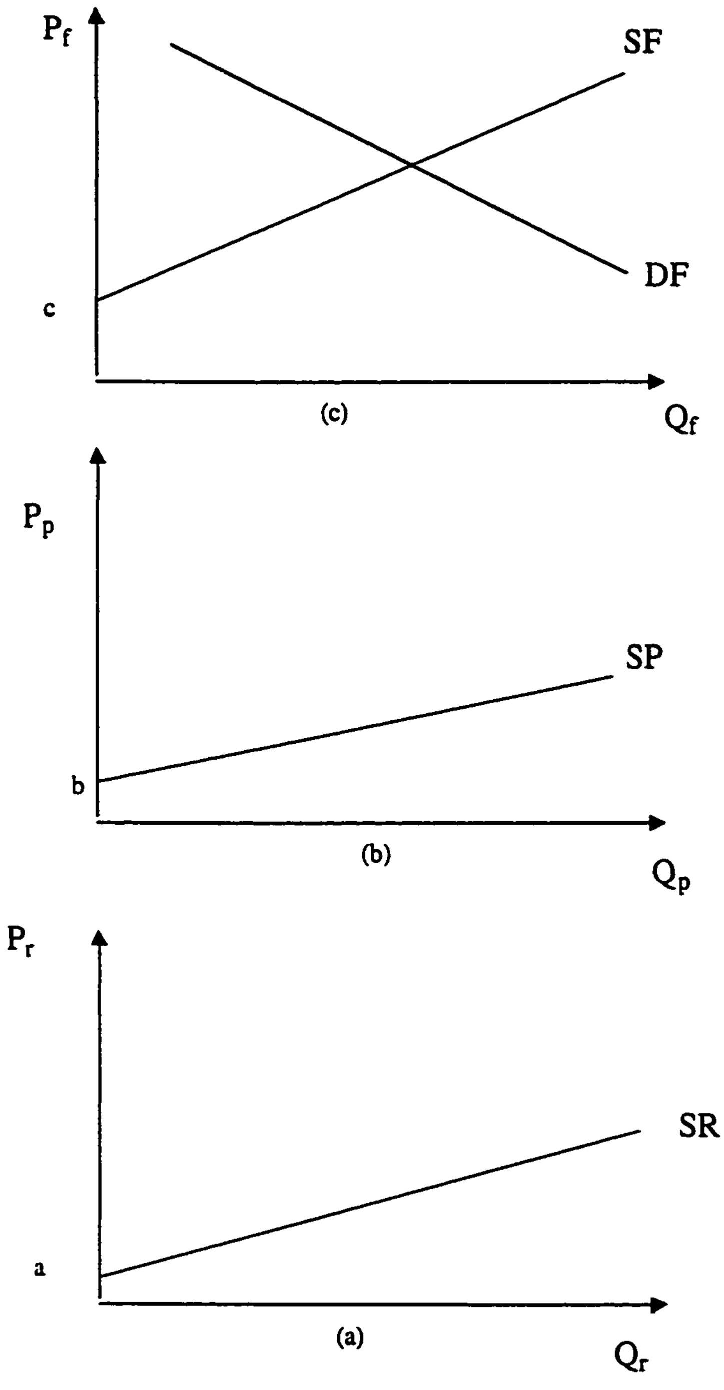

Figure 7. Vertically Related Markets

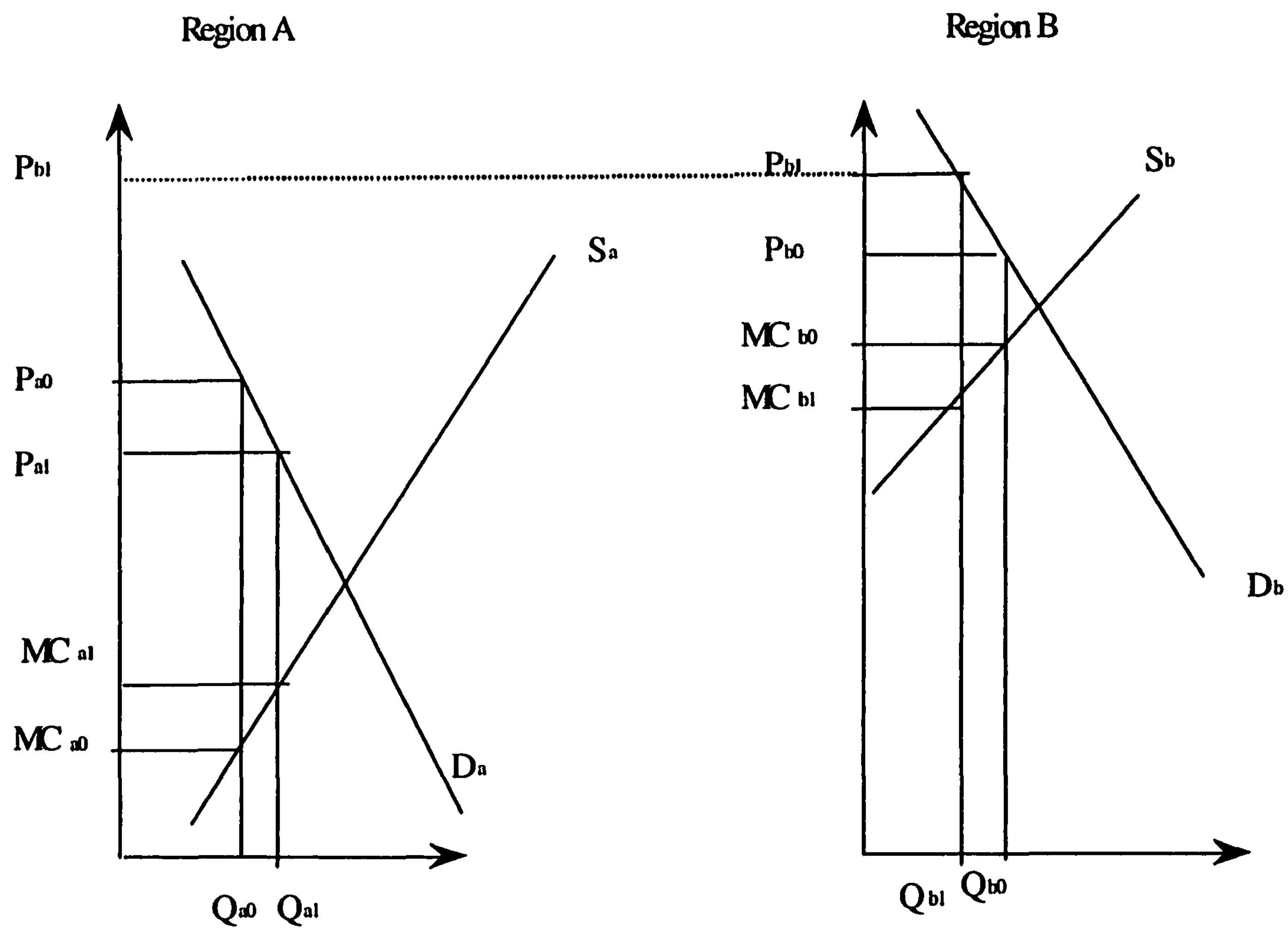

Figure 8. SPE Model for Milk and Quota (Source: Mussell and Goddard 1996)

Chapter 5 Empirical Model

The discussion relating to the theoretical model suggests that a partial spatial equilibrium model may have the aspects desired for this study. However, most of the existing agricultural SPE models lack sufficient detail to be used for the Canadian dairy industry. An exception is the Canadian Regional Agricultural Model (CRAM). In its modeling of the Canadian agricultural sectors, CRAM has some of the required detail, which includes the highly desirable feature of having inter-linkages between the dairy sector and other agricultural sectors. The choice of CRAM as a base model allows a reasonable level of detail in the dairy sector. While building a new SPE model is possible, incorporating all the details of inter-linkages with other agricultural sectors in Canada is difficult. In doing so, it may be necessary to do as much work as was needed to get a reasonable level of detail in the dairy sector. As a result, in this study, the spatial price equilibrium mathematical programming model for the Canadian dairy section has been adapted based on the current version of CRAM. In order to provide some background, a brief overview of CRAM[18] is provided in the following section.

5.1 Overview of Canadian Regional Agricultural Model (CRAM)

CRAM was developed in 1985-86 at the University of British Columbia by Webber, et al. (1986). Originally programmed in FORTRAN, the model was made more accessible and portable to a wider range of potential users when it was converted to the GAMS system (Brooke et al. 1988) in 1991.

CRAM is a regional, multi-sector, comparative static, partial equilibrium mathematical programming model of Canadian agriculture. It simulates the production, consumption and transportation of the major agricultural commodities produced in Canada. The model solves for the quantitative levels of agricultural activities which maximize a modified welfare function - the sum of consumer surplus and producer surplus less processing and transport costs. The model optimizes production of these commodities for a single year subject to a set of linear constraints that reflect agricultural resources and final demands for producers (Klein et al. 1993). In CRAM, five disaggregated geographical levels are used to represent agricultural activities in Canada: the national level, eastern and western Canada, the provincial level, crop regions in the Prairies, and export/shipping points. Currently, there are 10 provinces, 29 crop producing regions and two export ports (i.e., Vancouver and Thunder Bay) in the model. The model has approximately 2300 variables and 1300 equations (Horner et al. 1992).

Three major types of equations can be identified in CRAM: resource constraint equations, commodity balance equations, and ratio equations. Resource constraint equations specify opening and closing livestock numbers for livestock and land availability. Two major sets of production activities are defined in the model – those dealing with crop (or forage production) activities and those dealing with livestock. The crop production section in the model represents Canada's 29 crop regions producing wheat, barley, flax, canola, corn, soybeans, hay, pasture and other crops. Livestock production is modeled at the provincial level for beef, hog, dairy and poultry. Shipments

[18] Detailed information on the current version of CRAM is provided in the technical report by Horner et al. (1992).

of livestock, livestock products and grains occur to meet provincial demand levels. Opening inventories of livestock herds and poultry flocks are adjusted through incorporation of retention functions responding to own prices and feed grain price effects. Trade in red meats, grains, dairy and poultry products requires that export and import prices be established (Horner et al. 1992).

Commodity balance equations deal with supply utilization for each of the demanded commodities in each region and ensure that demand does not exceed supply. CRAM also has a set of transportation equations to simulate the inter-provincial trade for most of the crops, some live animals (e.g., slaughter cattle, feeders, and hogs) and some processed dairy products (e.g., cheese and butter). The domestic sales balance constraints determine the level of the commodity demanded and the prices for crop, livestock, and dairy products. These prices and quantities are then used to calculate consumer and producer surplus, which are added into the objective function. Some products are specified as eastern or western Canadian sales (e.g., dairy products); others are treated at a national level without regional disaggregation (Horner et al. 1992).

Ratio equations define certain biological relationships in the beef, pork, and dairy sectors. This block also defines some technical ratios, such as the components (e.g., butterfat) required per unit of each dairy product. Ratio equations also allocate national demand for some commodities to the provincial level according to population.

Canadian agricultural production activities are divided into two major groups in CRAM: crop production and livestock production. Products in the crop section include grains, oilseed and forages. The livestock section, includes beef, dairy, hogs, and poultry.

Among these commodities, crops and beef are "link" to the dairy sector and will be discussed in more detail. Each of these groups, has three general categories of activities modeled in CRAM: production, demand, and transportation.

5.1.1 Production Activities

5.1.1.1 Crop Sector

The crop production activities can be split into two parts: regional crop production activities and activities that transfer the crops produced to the provincial level where they can be used for livestock feed, domestic consumption, or shipped to a export port. Positive Mathematical Programming (PMP) is used in the crop section to calibrate a regional crop's specific supply function against a set of base data on prices, costs, yield, and area. "The PMP approach results in a large increase in the number of quadratic functions in the model, and far fewer linear constraints." (Horner et al. 1992, p.14). PMP is also applied in this study and is explained in detail in a later section (i.e., Chapter 6).

In order to model crop production, the following elements are necessary:

- Resource limitations to specify resource (e.g., land) requirements and availability.
- Summer-fallow ratio of land for each region to dictate the minimum amount of land that must be summer-fallowed each year.
- Cropping pattern constraints to specify historical cropping ratios within each crop production region.
- Crop production costs for fertilizers and chemicals, machinery repair and fuel, seed, insurance, and utilities.

- Crop yields to define the output of crop production based on different inputs. The yields employed are based on historical average yields. Those crops that are used for feed have production specified at the provincial level.
- Diets for livestock feed that are expressed in terms of stored forage, pasture, and barley for beef and dairy animals; barley for hogs; and wheat for poultry. To ensure feed requirements are met, limited substitution of feed is allowed.

All regional production of wheat, barley, flax, canola, and corn grain is first transferred to the provincial level. Shipments to other provinces are taken from the provincial supply. To allow the shipment of crops between province, unique transportation costs are associated with each transfer activity.

5.1.1.2 Beef Production

Compared with crop production, beef production is more complex because of the length of the cattle cycle. Two years can be required before a calf is marketed or joins the breeding herd. CRAM is able to simulate these different stages.

In order to model beef production, the following elements are necessary:

- Opening stock and closing stocks of beef in the model must be divided into five categories: breeding herd, replacements, stockers, feedlot calves and feedlot long yearlings. The numbers of animals in each of these are specified as the maximum number possible.
- To model herd expansion or reduction, the closing stock numbers or the various classes of beef animals must be changed through the use of retention functions. The

constraints on the number of replacements include replacement ratio and numbers culled. The slaughter of yearlings is also adjusted for death loss.

- The model must have input requirements or costs for forage, pasture, barley and other cash costs. The annual diet of an animal consists of a mixture of forage, pasture, and barley, taken from the provincial supply.
- The model must include the beef yield, which defines the number of animals slaughtered. The yield is divided into two groups: high quality beef yield and low quality beef yield. A specific proportion of the opening stock of cows is cull yield low quality beef. The split is roughly 77% high quality beef and 23% low quality beef.
- To ensure that the model solution contains an adequate number of bulls, the model must have the ratio of cows to bulls.

5.1.1.3 Dairy and Other Production Activity

In the current CRAM model, milk production is controlled under the dairy supply management system, so that output is not affected by price changes such as those of the market milk price or the input price. The general structure of the dairy industry model is based on the approach followed by Short and Cote (1986), who assumed that supplies to the market at a national level were fixed for fresh milk, industrial milk and cream. Short and Cote's model balances milk supplies, fat (BF) and solid-not-fat (SNF) supplies with demands for milk sold and/or used to manufacture different dairy products. More detailed discussion will be provided later in this chapter.

Poultry and hog production is also included in CRAM. Detailed information for these two sectors is provided in the technical report by Horner et al. (1992).

5.1.2 Demand Activity

In the current CRAM, domestic demand is mostly specified for western and eastern Canada. In each region, demand is distributed over the provinces on a per capita basis or share of actual disappearance if the required information is available. The quantity demanded in each region is determined by the use of linear demand functions, which are determined within the model given user-provided equilibrium (historical) prices, quantities and elasticities. Shipping activities allow for the movement of goods among provinces and to the world to ensure domestic demand is met. Trade with the world is treated as a residual activity that balances domestic demand and supply.

5.1.3 Transportation Activities

In CRAM, trade can occur among all levels of the aggregated region: provinces, ports, and the world. In the dairy sector, it is assumed that only industrial dairy products are shipped either inter-provincially or internationally. The flows of trade are determined by the available supply, level of demand within a region, and the cost of transportation. The transportation costs for crops are deducted from the "export" price to calculate the farm gate price. The transportation costs for dairy product, red meats, live animals and poultry are explicitly accounted for in CRAM.As well, total export receipts from each province to the world and import costs to each province from the world are tallied in a Canadian export total and a Canadian import total. Total transportation costs are then transferred to the objective function where imports enter as a cost and exports enter as revenue.

5.1.4 Previous Applications of CRAM

One of the first applications of CRAM was to look at the implications of the introducing medium quality wheat on the Prairies (Webber, et al. 1986). Since then CRAM has been used to examine the impact of the 1985 U.S. Food Security Act on the Canadian grains sector (MacGregor and Graham 1989) and the impact of the direct government assistance program on the beef and hogs sectors (Graham and MacGregor 1989). CRAM has also been employed within Agriculture Canada to examine the implications of the Canada-U.S. Trade Agreement (CUSTA), the Multilateral Trade Negotiations (MTN) (Graham et al. 1990) and the Western Grain Transportation Act (WGTA) (Klein et al. 1991). The CRAM model has been used by Graham et al. (1990) to examine the effects of trade liberalization on the dairy and poultry sectors in Canada. Klein et al. (1993) applied CRAM in studying transportation issues related to free trade agreements in Canadian agriculture. Most of these research efforts resulted in major modifications and extensions of the CRAM model, and this evolutionary process will continue as new issues are addressed within the CRAM framework. CRAM is further modified in this study in order to achieve the study objective, with particular attention being given to the dairy sector.

5.2 Dairy Block in CRAM

The milk production, processing and marketing activities are defined on a province by province basis. Provincial level fresh milk supplies are linked to provincial level demand functions, and shipment of manufactured products provinces takes place in order to balance supplies and demands in each of the provinces and to take advantage of any arbitrage opportunities. In order to incorporate the dairy industry into the theoretical model, four general categories of activities need to be incorporated in addition to the objective function: production activities, demand activities, transportation activities, and government activities.

5.2.1 Livestock Numbers

In CRAM, the dairy production block contains a significant amount of detail for dairy livestock. The total number of dairy livestock effectively set a resource limitation for milk production in each province. Livestock in the dairy block also provide a linkage between the dairy sector and beef sector as well as a linkage between the dairy sector and crop sector.

CRAM models the livestock numbers in the dairy sector on a provincial basis. The model endogenously determines numbers of cows, heifers and heifer calves.[19] A set of constraints "limits" the numbers of animals in the various age classes. These constraints include a user specified upper limit on opening stocks (i.e., beginning numbers) for each class and a set of dairy livestock constraints.

[19]In CRAM, it is assumed that bull calves are moved into a veal enterprise, which is treated separately from the dairy sector.

Dairy Opening Stocks Constraints For Each Province

(5.2-1) $DAIRYPRODA(x) \leq OSDAIRY(x),$

where

DAIRYPRODA(x) is a variable representing dairy production animal in province x;

OSDAIRY(x) is a variable representing opening stock of dairy animal in province x.

This constraint places an upper limit on the total numbers of animals in each class (i.e., cow, heifers and calves) in the provincial dairy herd, based on the user provided parameter: OSDAIRY.

Dairy Herd Balance Constraints for Each Province

(5.2-2) $DCULLEDHEIFERS(x) + CSCOW(x) \leq (1 - CULLRATE - DSCOW) * OSCOW(x)$

$+ (1 - DSHEIFERS) * OSHHEIFER(x)$

where

CULLRATE is the culling rate for cows;

CSCOW(x) is a variable representing closing stock of cows in province x;

DCULLEDHEIFERS(x) is a variable representing dairy culled heifers in province x;

DSHEIFER is death rate for heifers;

DSCOW is death rate for cows;

OSCOW(x) is a variable representing opening stock of cows in province x;

OSHHEIFER(x) is a variable representing opening stock of heifers in province x.

This constraint connects the opening stock of livestock and closing stock of livestock, taking into account movement of heifers to cows, culling rate, and death losses.

Dairy Calf Balance Constraints for Each Province

(5.2-3) $CSCALVES(x) + VEALCALVES(x) + CALVESTOBEEF(x) \leq CALFRATE * (1 - DSCALVES) * OSCOW(x) + CALFRATE * (1 - DSHEIFER) * OSHHEIFER(x),$

where

CALVESTOBEEF(x) is a variable representing calves transferred to beef in province x;

CSCALVES(x) is a variable representing closing stock of calves in province x;

DSCALVES is death rate for calves;

DSHEIFER is death rate for heifers;

OSCOW(x) is a variable representing opening stock of cows in province x;

OSHHEIFER(x) is a variable representing opening stock of heifers in province x;

VEALCALVES(x) is a variable representing veal calves in province x.

This constraint ensures that the total numbers of calves (i.e., heifer, veal and transferred calves) are no greater than the available calves when considering the calving rate and death rate for calves.

5.2.2 Milk Production

In CRAM, total milk production in each province depends on the total available dairy cows and the milk production per cow. The relationship is presented in the following constraint:

Total Milk Production Constraints for Each Province

(5.2-4) $DMILKPROD(x) \leq OSCOW(x) * MILKCOW(x)$,

where

DMILKPROD(x) is a variable representing total milk production in province x;

OSCOW(x) is a variable representing opening stock of cows in province x;

MILKCOW(x) is a variable representing milk production per cow in province x.

This constraint places an upper limit on the milk production, which depends on the beginning numbers of dairy cows.

The costs of the dairy sector are incorporated in the objective function. A cost of production per animal is specified for each class within the dairy herd. These costs vary by province. The cost of milk production in CRAM represents the variable costs per animal, excluding feed costs.[20]

After the raw milk is produced, a certain amount is delivered as different milk categories: fluid milk, industrial milk, or industrial cream.

Milk Balance Constraints for Each Province:

(5.2-5) $INDUSTRIALMILK(x) + FLUIDMILK(x) + INDUSTRIALCREAM(x) + QMILK(x)$

$\leq DMILKPROD(x)$,

where

DMILKPROD(x) is a variable representing total milk production in province x;

FLUIDMILK(x) is a variable representing milk allocated to fluid milk in province x;

[20] Milk production costs used in CRAM exclude costs for energy and forage feed stuffs (i.e., barley, hay, and silage). However, the cost of protein supplements such as canola or soybean meal is included.

INDUSTRIALMILK(x) is a variable representing milk allocated to industrial milk in province x;

INDUSTRIALCREAM(x) is a variable representing milk allocated to industrial cream in x;

QMILK(x) is a variable representing over-quota milk production in province x.

These equations allocate raw milk from the farm sector to one of four uses: the fluid milk market, industrial milk market, over-quota milk, and industrial cream. A ratio of fluid to industrial milk per province ensures that the fluid quota levels are not surpassed. The rest of the milk goes to one of the three industrial supplies.

5.2.3 Dairy Product Processing and Milk Components

In the original version of CRAM, seven types of dairy products were specified: fresh milk, low fat milk, cream, cheese, butter, skim milk powder and other dairy products. A set of balance equations for Butter Fat (BF) and Solid-Not-Fat (SNF) constrain production in that the total BF and SNF used in the manufacture of the different dairy products is less than or equal to supplies delivered by farmers in the form of fluid milk, industrial milk and farm separated cream (Horner et at 1992).

Fluid Butterfat Balance Constraints for Each Province:

(5.2-6) $\Sigma_i DAIRYPROC(x)_i * FATREQ_i + DTRANS(x) \leq FMILK(x) * FATCON(x)$,

where

$DAIRYPROC(x)_i$ is production of fluid dairy product i in province x;

DTRANS (x) is a variable representing BF transfer from fluid to industrial milk in province x;

$FATREQ_i$ is unit requirement of fluid dairy product i;

FMILK(x) is a variable representing fluid milk production in province x;

FATCON is butterfat content of raw milk in province x.

<u>Industrial Butterfat Balance Constraints for Each Province</u>

(5.2-7) $\sum_i DPPROD(x)_i * FATREQ_i \leq$

$IMILK(x)*FATCON(x) + ICREAM(x)*FATCON(x) + QMILK(x)*FATCON(x) + DTRANS(x)$

where

$DPPROD(x)_i$ is production of processed dairy product i in province x;

DTRANS(x) is a variable representing BF transfer from fluid to industrial milk in province x;

FATCON(x) is a variable representing butterfat content of raw milk in province x;

$FATREQ_i$ is the amount of butterfat required per unit of processed dairy product i;

IMILK(x) is industrial milk production in province x;

ICREAM(x) is a variable representing industrial cream production in province x;

QMILK(x) is a variable representing over-quota milk production in province x;

<u>Fluid Milk SFN Balance Constraints for Each Province</u>:

(5.2-8) $\sum_i DAIRYPROC(x)_i *SNFREQ_i + DTRANS(x) *SNFREQ \leq FMILK(x) *SNFCON$

where

$DAIRYPROC(x)_i$ is production of fluid dairy products i in province x;

$SNFREQ_i$ is SNF required per unit of fluid dairy product i;

SNFTRANS(x) is a variable representing SNF transfer from fluid to industry milk in province x;

SNFCON(x) is a variable representing SNF content of raw milk in province x.

<u>Industrial SNF Balance Constraints for Each Province</u>:

(5.2-9) $\Sigma_i DPPROD_i(x) * SNFREQ_i \leq$

$$IMILK(x)*SNFCON(x) + ICREAM(x)*SNFCON(x) + QMILK(x)*SNFCON(x) + SNFTRANS(x)$$

where

$DPPROD(x)_i$ is production of processed dairy product i in province x;

IMILK(x) is industrial milk production in province x;

ICREAM(x) is a variable representing industrial cream production in province x;

QMILK(x) is a variable representing over quota milk Production in province x;

$SNFREQ_i$ is SNF required per unit of processed dairy product i;

SNFCON(x) is a variable representing SNF content of raw milk in province x;

SNFTRANS(x) is a variable representing SNF transfer from fluid to industry milk in province x.

These four sets of equations decompose the different supplies of milk into their BF and SNF components. Any excess fluid milk components may transfer into industrial uses. For example, DTRANS(x) allows for BF transfer from the fluid milk category to that of industrial milk. The final products draw milk components from their respective supplies, ensuring that the amounts of BF and SNF used by the fluid or industrial production do not exceed the amounts available. The average cost for processing dairy products is incorporated in the objective function and is subtracted from the total welfare measurement.

5.2.4 Linkages to Other Agricultural Sectors In CRAM

CRAM has the feature of having inter-linkages to other agricultural sectors in Canada. On the milk production side, producers use forage and feed grain as inputs to produce milk as well as producing beef as a by-product of milk production. Feed requirements for barley, forage and pasture (tonnes/animal) are specified for each class of animal. The forage is assumed to be hay, but other forages (e.g., corn silage) can also be used and are converted to hay equivalents. The "energy" feed stuff is assumed to be barley, but other feed (e.g., corn) can also be used and are converted to barley equivalents. The costs of these feeds are accounted for through crop production costs within the cropping block of CRAM. Commodity equations limit the transfer of feeds into the dairy sectorand are presented and explained below:

<u>Forage Balance Constraints for Each Province</u>

(5.2-10) $$\Sigma_d(FDA_d(x)^* \; OSDAIRY_d(x)) + FOL(x) \leq TFA(x),$$

where

$FDA_d(x)$ is a variable representing per dairy animal forage requirement for dairy animal class d;

$FOL(x)$ is a variable representing forage used by other livestock in province x;

$OSDAIRY_d(x)$ is a variable representing opening stock for dairy animal class d in province x;

$TFA(x)$ is a variable representing total forage available in province x;

This constraint states that the total usage of forage in each province cannot exceed its total production of forage.

Barley Balance Constraints for Each Province

(5.2-11) $$\Sigma_d(BDA_d(x) * OSDAIRY_d(x)) + BOL(x) \leq TBA(x) + GTOB(x)$$

where

$BDA_d(x)$ is a variable representing per animal barley requirement for dairy animal class d;

$OSDAIRY_d(x)$ is a variable representing opening stock for dairy animal class d in province x;

$BOL(x)$ is barley used by other livestock in province x;

$TBA(x)$ is a variable representing total barley available in province x;

$GTOB(x)$ is a variable representing total feed grains transferred to barley in province x;

This constraint states that the total usage of barley (or equivalent crop) in each province cannot exceed its total production of barley or equivalent grain.

As a by-product of milk production, culled animals (i.e., cows, heifers, heifer calves) are transferred to the beef sector in each province. The following beef constraints ensure that the total tonnes of beef slaughtered in the province do not exceed the tonnes available:

Slaughtered Beef Cows Constraints For Each Province

(5.2-12) $CSLAUGHTER(x) \leq OTHERBEEF(x) + BEEFCOW(x)*CULLRATE *OSCOW(x)$

where

BEEFCOW(x) is a variable representing dressed beef per cow in province x;

CSLAUGHTER(x) is a variable representing tonnes of slaughtered cows in province x;

CULLRATE is the culling rate for cows;

OTHERBEEF(x) is a variable representing tonnes of beef from other sources in the beef sector in province x;

OSCOW(x) is a variable representing opening stock of cows in province x;

Slaughtered Beef Heifers And Steers Constraints For Each Province

(5.2-13) $HCSLAUGHTER(x) \leq OTHERBEEFHC(x) + BEEFHEIFER(x)*CULLEDHEIFERS(x) + BEEFCALF(x)*CULLEDCALVES(x),$

where

HCSLAUGHTER(x) is a variable representing tonnes of slaughtered heifers and calves in province x;

OTHERBEEFHC(x) is a variable representing tonnes of beef from other sources in the beef sector in province x;

BEEFHEIFER(x) is a variable representing dressed beef per heifer in province x;

BEEFCALF(x) is a variable representing dressed beef per calf in province x;

CULLEDHEIFERS(x) is a variable representing the number of culled heifers in province x;

CULLEDCALVES(x) is a variable representing the number of culled calves in province x.

These two constraints ensure that the beef shipped within a province to itself, other provinces and exported does not exceed the supply of beef in the province. The culled dairy animals are added into the appropriate beef supply relationship.

5.2.5 Transportation Cost of Dairy Products

Transportation cost is incorporated in the objective function and subtracted from the total welfare measurement. In the current CRAM, raw milk and fluid milk products are not allowed to transfer across the provinces. In CRAM, the unit transportation costs for industrial dairy products are calculated by the following linear formula:

$$UTC = 1 + 0.03 * X, \qquad (5.2\text{-}14)$$

where

UTC is unit transportation cost ($/tonne);

X is distance (Kilometer) between two transportation points.

The unit transportation cost is multiplied by the spatial distance between two transportation points. The distance between each possible transportation point is specified by using a distance matrix.

5.2.6 Demand for Dairy Products

Once the products have been manufactured they move through to the demand sector for dairy products. This movement occurs through the use of the transfer rows that link the manufacturing sector to transport and demand activities in CRAM. The quantity demanded in each region is determined through the use of linear demand functions, which are determined within the model based on historical data for prices, quantities and elasticities for different dairy products. The consumer welfare is then derived from the demand function and maximized in the objective function. In the constraints, domestic demands are specified at a regional level (i.e., western Canada, eastern Canada, the provincial level, and the national level). Shipping activities allow sufficient movement of goods among provinces and around the world to ensure that domestic demand is met. Within the western and eastern regions, demand is distributed over the province on a per capita basis. The following balance restrictions are set up in the model:

Provincial Commodity Balance Constraints for Each Dairy Product in Each Province :

(5.2-15) $\sum_j DAIRYSEXP_{j,n}(x) + DAIRYD_n(x) \leq DPPROD_n(x) + \sum_j DAIRYSIMP_{j,n}(x),$

where

$DAIRYSEXP_{j,n}(x)$ is a variable representing shipment of dairy product n from province x to

province j;

$DAIRYD_n(x)$ is a variable representing demand for dairy product n in province x;

DPPROD(x) is a variable representing production of dairy product n in province x;

$DAIRYSIMP_{j,n}(x)$ is a variable representing shipment of dairy product n from province j to

province x.

This constraint states that the total dairy products demand within a local province and the sum of total exports to other provinces cannot exceed the total product production of this dairy product plus shipments from other provinces.

<u>Dairy Products Export Constraints</u>:

(5.2-16) $$\sum_j DAIRYEXP^d{}_{ca,j}(x) < \sum_i DAIRYEXP^S{}_{i,ca}(x)$$

where

$DAIREXP^d{}_{ca,j}$ is total dairy export shipment from Canada to country j in the world;

$DAIREXP^s{}_{i,ca}$ is total dairy products available from each province i to export by Canada.

This constraint states that the total exports of Canadian dairy products cannot exceed the total available amount. In CRAM, the world market is considered as a place to "dump" the residual dairy products.

5.2.7 Government Activity

Governments intervene in the dairy industry by setting the quotas for fluid and industrial milk and setting the target price for the dairy products. Governments also collect levies and provide subsidies according to earlier discussed programs. Levies and subsidies are incorporated as costs or revenue, respectively, in the objective function. The quantity controls of milk production by government are incorporated as following:

Market Share Quota Constraint:

(5.2-17a) $DPRIMPRODI(x)*FATCON(x) \leq QUOTAI(x) + QMILK(x)$

Fluid Milk Quota Constraint:

(5.2-17b) $DPRIMPRODF(x) \leq QUOTAF(x)$

where

DPRIMPRODI(x) is a variable representing industrial milk producing in province x;

DPRIMPRODF(x) is a variable representing fluid milk producing in province x;

FATCON(x) is a variable representing the BF content of raw milk in province x;

QMILK(x) is a variable representing over quota milk in province x;

QUOTAI(x) is a variable representing quota for industrial milk in province x (expressed in BF equivalent);

QUOTAF(x) is a variable representing quota for fluid milk in province x.

These two sets of constraints ensure that milk production in each province does not exceed quota levels. Excess industrial milk production goes into over quota milk. The butterfat subsidy along with the sum of in-quota and over-quota levies is associated with the activities for the four basic milk supplies. The fluid market milk has a skim-off levy to cover the movement of butterfat to the industrial sector. The industrial milk (within the MSQ) is charged an in-quota levy, but also receives the butterfat subsidy. Over-quota milk production is charged the over-quota levy.

5.3 Objective Function for the Dairy Sector

In the existing CRAM model, the portion of the objective function that deals with the dairy sector maximizes the sum of the areas under the demand curves minus total milk production and processing costs, transportation costs, and government levies in all provinces. This represents a simplification of producer surplus as total milk production and processing costs are included in the objective function instead of true supply functions. However, this simplification is valid only if the underline supply function is infinitely elastic.

In this study, producer surplus is incorporated in the objective function in order to maximize the sum of the consumer surplus and producer surplus minus the total transportation cost ($t_{n,i,j}$) in the dairy sector. Production activities in the objective function include two different market levels: raw milk production ($p^{s1}{}_{i}$) and dairy products processing ($p^{s2}{}_{n,i}$).

$$Max: \sum_{n,j} \int_0^{D_{n,j}} P^d_{n,j}(x)dx - (\sum_{m,i} \int_0^{S_{m,i}} P^{S1}_{m,i}(y)dy + \sum_{n,i} \int_0^{S_{n,i}} P^{S2}_{n,i}(y)dy)$$

(5.3-1)

$$- \sum_{m,i,j} X_{m,i,j} t_{m,i,j} - \sum_{n,i,j} X_{n,i,j} t_{n,i,j} - \sum_{m,i} S_{m,i} . G_{m,i} - \sum_{n,i} S_{n,i} . G_{n,i}$$

where

$S_{m,i}$ = production of the m-th raw milk commodity in region i, m = 1,...,M and i = 1,...,I;

$S_{n,i}$ = production of the n-th final dairy product in region i, n = 1,...,N and i = 1,...,I;

$D_{n,j}$ = consumption of the n-th final dairy product in region j, n =1,...,N and j = 1, . . . J;

$X_{m,i,j}$ = exports of the m-th raw milk commodity from region i to region j, i = 1,...,I and j= 1,...,J;

$t_{m,i,j}$ = unit cost of transporting the m-th raw milk commodity from region i to region j, n=1,...,N, i = 1,...,I and j = 1,...,J;

$X_{n,i,j}$ = exports of the n-th final dairy product from region i to region j, n = 1,...,N, i = 1,...,I and j= 1,...,J;

$t_{n,i,j}$ = unit cost of transporting the n-th final dairy product from region i to region j, n = 1,...,N, i = 1,...,I and j = 1,...,J;

$G_{m,i}$ = Government net levies (or subsidies) on the m-th raw milk commodity in region i, m = 1,...,M and i = 1,...,I;

$G_{n,i}$ = Government net levies on the n-th final dairy product in region i, n = 1,...,N and i = 1,...,I;

$P^{D}{}_{n,j}$ = Quantity-dependent Marshallian demand function for the n-th final dairy product in region j, for n = 1,...,N and j = 1,...,J;

$P^{SI}{}_{m,i.}$ = Quantity-dependent supply function for the m-th raw milk commodity in region i, m=1,...,M, i = 1,...,I;

$P^{S2}{}_{n,i} =$ Quantity-dependent supply function for the n-th intermediate commodity in region i, n = I,...,N and i = 1,...,I.

A detailed discussion of the producer and consumer activities in the objective function is provided in the following section.

5.4 Updating Dairy production Activities in CRAM

5.4.1 Milk Production per Cow

Milk production per cow provides the link in CRAM between livestock numbers and milk supply. Since genetic progress in provincial dairy herds has resulted in gradual increases in milk productivity per cow, the updating of these parameters is necessary.

Several potential sources of data may be used to estimate milk production per cow. Provincial milk volumes are published in the *Dairy Review* (Statistics Canada 1998). These may be combined with provincial dairy cow numbers (Statistics Canada 1996a) to estimate the volume of milk per cow. While this method has the advantage of data availability, it has limitations. Specifically, this approach underestimates the production per cow for commercial dairy herds, as it includes cows from all farms with cows, regardless of the amount of milk shipped from those farms. Alternative sources of milk production figures include published values from cost of production studies, averages from Dairy Herd Improvement Association (DHIA) records, etc. These values tend to provide somewhat higher estimates of milk production per cow. It was decided that cost of production studies would provide estimates that were more representative of commercial dairy production.

Production figures from other sources (e.g., the Ontario Dairy Farm Accounting Project, DHIA, Appleby 1996) were available for three provinces: Quebec, Ontario and Alberta. The average production per cow values from these studies were compared to the corresponding values obtained from using the estimates of provincial milk volume and cow numbers, as noted above. It was determined that, on average, the values based on the cost of production studies were approximately 18 percent greater than those in the other estimates. This value was then used as a scaling factor to adjust the production figures for the remaining seven provinces up to values that were believed to be more representative of production levels for commercial dairy operations. The resulting updated milk production estimates are presented in Table 5.

5.4.2 arginal Cost of Milk Production and Milk Processing

As noted in previous discussion, the calculation of producer welfare for dairy production in CRAM's objective function is simplified through assumption of constant average and marginal costs for milk production. However, to assess the impact of trade liberalization scenarios on the dairy sectors of Canada the supply functions for this sector must be determined. These may be specified through the inclusion of marginal cost relationships for milk production. Unfortunately, the marginal cost for milk production is not directly observable from market prices.

The dairy supply management system involves both pre-determined producer price and fluid marketing quota for raw milk production in Canada. As a result, a gap normally exists between the prices received by producers and the marginal cost of production. The gap can be interpreted as the rental rate of the marketing quota. The relation can be explained by the following equation (Chen & Meilke 1998; Moschini 1988) as long as the quantity of the quota is not equal to equilibrium production in the free market:

$$MC(Y) = P - R,$$

where $MC(Y)$ is the marginal cost, Y is the quantity of milk produced, P is the output price and R is the rental value of the quota. Because quota rental is prohibited in the Canadian dairy industry, the rental value is unknown, and, therefore, the marginal cost information for raw milk production is not directly observable (Chen and Meilke 1998).

In the past two decades, various approaches have been proposed to obtain the marginal cost for Canadian milk production. The econometric method can be used to estimate a cost or profit function for each province. However, this approach requires large amounts of farm level data for each region which are not easily obtained. The most direct approach to obtain a value for the marginal production cost is to use cost of production survey data as an approximation of the marginal production cost (e.g., Barichello et al. 1987; Barichello and Stennes 1994). However, production survey data only provide information only on average costs. Only if the sector is in long run competitive equilibrium will the average cost be equal to the marginal cost. Moreover, Chen and Meilke (1998) argued that a drawback of directly using average cost data is that the cost data used to approximate the cost function are also used by regulatory agencies to set the price of milk. Since the milk producers participating in the cost of production surveys know this, there is a common suspicion that costs are inflated. In this study, an approach developed from Positive Mathematical Programming is used to obtain the unobservable marginal production cost from the observed average cost of milk production.

A similar argument may be made concerning the importance of incorporating a supply relationship for dairy processing. For the dairy processing products, the marginal processing cost information is also difficult to obtain for individual processing plants. A study of the marginal processing costs at the provincial level has not been carried out. As similar approach (PMP) will also apply to the marginal processing cost of dairy processing products. More detail concerning this approach is provided in Chapter 6.

5.4.3 Average Cost of Milk Production

In this study, the marginal cost of milk production was obtained by using the PMP methodology that only require the initial value of average cost information. There is not a single data source available for these data requirement, several sources are used to obtain this information. There are 1995 provincial milk production budgets for New Brunswick, Quebec, Ontario and Manitoba from the Canadian Dairy Commission. Beginning in 1996, CDC provincial budgets have been available for other provinces, except British Columbia, Newfoundland and Alberta. For those provinces with only 1995 budgets available, the data from later years were converted back to the level of 1995. These data were adjusted to the 1995 "100%" estimate by using a scaling factor based on relative 1996 costs for other nearby provinces. The CDC uses the estimates to calculate target returns for industrial milk, and as such, these estimates represent the average for the top

70% of the most cost efficient producers in each province in terms of the cost per hectoliter of milk.

For Alberta, the 1995 average costs of production were obtained from the published results of the annual provincial survey (Appleby 1996). This budget is based on 100 percent of the survey sample, rather than on 70 percent as for the other provinces. This figure was adjusted to a top 70% figure by reducing the eligible costs by 25.6 percent. This scaling factor was obtained by comparing the cost of production estimate obtained from the CDC for Ontario with a similar figure for the entire Ontario sample (Ontario Dairy Farm Accounting Project 1997).[21] The variable costs, by cost category, are provided in Table 6.

Another adjustment for these costs of production is to exclude any costs associated with feed purchase and/or crop production. As noted early, for a vertical production model, no cost for any particular production level should not be double counted. In order to obtain the production cost parameter to be used in model, these budgets must first be adjusted to include only eligible variable costs (i.e., non-feed costs). The cost categories included in this value are breeding, transportation, promotion and other fees, veterinary, fuel and oil, repair costs for machinery, equipment, land and buildings, property taxes and insurance, hydro and telephone, hired labour and other miscellaneous costs. It was decided to include, based on expert opinion, 50 percent of those costs that could be allocated to both cropping and dairy enterprises (i.e., repairs, fuel and oil, property taxes and insurance). Therefore, 50 percent of machinery and

[21] Implicit in the use of this scaling factor is the assumption that the distribution of producers in Ontario and Alberta is similar, in terms of its shape (not location).

equipment costs are allocated to the dairy operation. After the cost allocation is done, a cost per hectoliter is calculated for each province for 1995. This cost (dollars per hectoliter) is then multiplied by production per cow to obtain the cost per animal to be included in model.

The only exceptions to this process were for British Columbia and Newfoundland. No production cost data are available for Newfoundland and British Columbia. The Alberta cost estimate was used as a proxy for British Columbia, and the average of the costs for the other three Maritime provinces (i.e., Prince Edward Island, Nova Scotia and New Brunswick) was used as a proxy for Newfoundland. The costs of milk production data are summarized in Table 6.

5.4.4 Average Cost for Dairy Processing

In the current version of the CRAM model, processing costs are provided for two types of fluid milk (i.e., standard and low fat) and five types of industrial milk products (i.e., cheese, butter, cream, skim milk powder, and other dairy products). These costs are assumed to be constant across provinces. Given the documentation provided in CRAM, it is unclear exactly how processing costs were derived for final dairy products in terms of sources, elements, composition, and representativeness.[22] To improve the processing cost block of the dairy segment of CRAM, a systematic procedure to collect the processing cost information is in order.

[22] Communication with Bob MacGregor, Policy Branch, Agriculture and Agri-Food Canada, has indicated that the existing processing costs were derived for final dairy products from an informal telephone survey of dairy processors.

Data from Statistics Canada - *Manufacturing Industries of Canada* (catalogue 31-203-XPB) - were used to derive estimates of average processing costs for each province. Two adjustments were needed to obtain data for the model. The first was to exclude the cost of raw milk from other material costs. This was done to provide a cost estimate consistent with the structure of multi-level production in the current model, as discussed in section 4.3.1. The second adjustment was to allocate the total variable cost among different products, as the census data are only available for fluid milk and other dairy products. To deduct the raw milk cost from other material costs, cash receipts for delivered fluid milk, cream, and industrial milk, respectively, were used as proxies. The cash receipts data were available from Statistics Canada (1998, catalogue number 23-001-QXPB) and were down loaded from Matrix 5651 of CANSIM.

To allocate the total variable costs among different product types, information concerning the cost share (formally known as the cost flexibility) for each dairy product is required. One approach that can be used to allocate costs is to obtain the total variable cost of producing a particular dairy product by using the cost share of the corresponding product and the total variable cost of producing all dairy products. These two values (i.e., cost share and total variable cost for all products) are multiplied together to provide an estimate of variable cost for the specific product. Unfortunately, this cost share information is not readily available for dairy products. Therefore, a systematic way to allocate the total variable cost among major types of dairy products must be found.

In this study, the revenue share of the corresponding product is used instead of the cost share. However, some assumptions are required to justify this approximating approach. It is assumed that the dairy-processing industry in each province is multi-product by nature, faced with allocable variable production factors, is non-joint in products, and exhibits constant proportional returns (or homogeneous production function). More detailed information regarding this process is provided in Appendix B.

A multi-product technology is a reasonable assumption as many plants currently operate multi-product facilities in Canada (Rude 1992). Nevertheless, the variable inputs such as power, salary, and other material can also be reasonably assumed to be allocable. It is also reasonable to assume the proportional return of this variable input is constant (or that production is homogenous). For example, Lester (1988) and Salem (1987) both estimated the overall industry elasticities of scale to be approximately unity. One less reasonable assumption is product non-jointness as all milk products share a common input. Furthermore, butter and skim milk powder are technically joint products. Since data for the manufacturing cost of production are extremely difficult to obtain, these assumption have to be maintained in order to derive the unit cost of dairy products.

Under these assumptions, the revenue share for a particular dairy product in each province can be shown as being equal to the cost share of the corresponding dairy product (Appendix B). The revenue share for particular dairy products in each province can be calculated from Statistics Canada (1995, *Products Shipped by Canadian Manufacturers)*. Approximating the cost share of a product by the revenue share of the corresponding product, the total variable cost of product is calculated by multiplying the cost share of the corresponding product by the total variable cost for all products. Due to missing values from the original data, the processing costs for fluid milk products and industrial dairy products in Manitoba, Saskatchewan, and the Atlantic Provinces were not available. For these provinces, values from neighboring provinces were used instead. The average cost estimates are presented in Table 18.

5.4.5 Supply Elasticities

For the milk production and milk processing sectors, the supply elasticities are required to derive the upward slopping supply curves. The difficulty of estimating supply elasticities in the Canadian dairy industry is well known (Moschini 1988), as observing producers' responses to the price changes in the market is difficult. Empirical estimations for the supply elasticities for both milk production and milk processing in Canada have not been carried out.

Meilke et al. (1998) argue that since the United States and Canada have similar production practices and face similar input prices, supply elasticities estimated from the United States data are indicative of the responsiveness of the underlying Canadian supply function. Given the geographic proximity of the U.S. market and the general availability of elasticity estimates for this market, it seems logical to survey the literature for supply elasticity estimates for the United States. After comparing eight previous studies in the United States, Meilke et al. (1998) used the value of one as the supply elasticity for milk production in Canada. The same value of supply elasticity (i.e., equal to one) of milk production was used in this study.

A study addressing supply elasticities for processed dairy products for Canada has not yet been published. A similar study for the United States is also not available.

The elasticities used in the current CRAM (and also in some internal reports of the Policy Branch of Agriculture and Agri-food Canada) were used for this study. In the current version of CRAM, a value of 1.0 is used as the supply elasticity is one for all the dairy processed products.

5.4.6 Supply Quantity

Supply quantities of raw milk and dairy products are used in CRAM to obtain the supply curves for milk production and milk processing. Specifically the quantities are used with prices and elasticities to recover the parameters for a linear supply function. Supply data for milk production were obtained from Statistics Canada publication and are presented in Table 1. The supply quantities for dairy products were obtained from Statistics Canada (Catalogue 23-001) and are presented in Table 2. However, data for most of the Maritime provinces and some of the western provinces were not available from original data sources. In the empirical model, these missing data are recovered using the weighted average (by the share of industrial milk quota in these provinces) and the total amount of dairy product output in these provinces. The total amount of dairy product output for those provinces with missing data were obtained from the difference between national dairy product output and the sum of the output for all the provinces for which data were available. Since the share of industry milk quota for these provinces is available (Table 3), this share is used to distribute the total amount of industrial dairy product supply to each of the provinces.

5.4.7 Other Dairy Farm Production Data

Many different parameters relating to the farm-level production of milk data are collected to update the base of CRAM to a 1995 level. These include feed and pasture requirements, other dairy costs and culling, death, calving and replacement rates. As noted earlier, genetic progress in provincial dairy herds results in gradual increases in milk productivity per cow. This, in turn, has impacts on other dairy production parameters such as feed requirements and costs of production. Within the model, feed requirements per animal are required for grain (i.e., expressed as tonnes of barley per animal per year) and forage (i.e., expressed as tonnes of hay per animal per year). Other potential sources of feed (e.g., corn and silage) are converted to either barley or hay equivalents. Any other feed requirements are not explicitly stated as model parameters. Instead, their costs are included in the production cost parameter for the cows. Similar steps are also taken for other classes of dairy animals.

One problem in updating these feed requirements is the lack of published data concerning rations fed to dairy animals. The basic approach used to establish feed requirement parameters for this study was to formulate rations for cows, based on nutrient requirements and nutrient content of ration ingredients. The nutrients considered in this analysis were net energy, crude protein, calcium, phosphorus, and acid detergent fiber. Minimum requirements for each nutrient were determined based on maintenance requirements and the level of milk production. As well, maximum dry matter intake levels were specified, based on body weight and milk production level. Assumptions were made concerning the body weight for the cow, fat content of the milk, and milk production levels. The production levels determined earlier for each province were used in this analysis. Published sources were used to establish these ration formulation parameters (National Research Council 1978). The ingredients considered for each ration were barley, protein supplement (i.e., soybean meal or canola meal) and hay (i.e., alfalfa-grass mixture). Published sources were used to establish "standard" nutrient content values for each ingredient (National Research Council 1978). Using this information, two rations were formulated for cows in each province; one for the lactation period and one for the "dry" period. In balancing these rations, it was assumed that producers would use as much home-grown forage as possible. The resulting annual feed requirements obtained from this procedure is provided in the Table 5.

Beside the feed requirements of the dairy cows, rations for other dairy animals such as dairy calves and heifers are also required in the model. It was assumed that the nature of the inputs required to raise dairy calves and heifers has not changed since 1988. As a result, the parameter values in the current CRAM were inflated to a 1995 basis by using the Farm Input Price Index for dairy farm inputs.

Because of the hedonic nature of the modeling for this study, the component ratios of raw milk are required for the model. Genetic progress in provincial dairy herds also results in gradual change in milk component, such as butterfat per unit of raw milk. This information is available from the dairy information center at the web site of Agriculture and Agri-food Canada. The content ratio parameters for milk production in each province are listed in Table 7.

The other production-related dairy parameters required by the model are the numbers of dairy cows, dairy heifers, heifer calves and veal calves. These are used to limit opening stocks to values that are representative of reality for the various classes of dairy livestock. Published sources were used to establish the dairy cow numbers and heifer calves (Statistics Canada 1996a). However, published livestock statistics typically include a single value for calves, including both dairy and beef calves. Instead, the calving rate and calf death loss parameters established in the previous section of this report were used, along with dairy cow numbers, to estimate the numbers of dairy calves. Assuming a 50:50 split between heifer and bull calves, the resulting calf number for each province is divided evenly between heifer calves and bull calves. The resulting provincial dairy livestock number estimates are provided in Table 1.

Along with milk, beef is also a product of the dairy sector in the model. Specifically, all categories of dairy animals (i.e., dairy cows, dairy heifers, heifer calves and veal calves) may be culled from the provincial dairy herd and transferred to the beef sector. "Transfer" constraints defining this relationship between the beef and dairy sectors are used in CRAM to allow for this transfer. In order to model this possibility, parameters indicating the "yield" of beef per animal must be included. These parameters were updated by using data obtained from AAFC. Table 8 provides the updated parameter estimates.

Besides the dairy production parameters estimates, as discussed above, additional miscellaneous dairy management parameters are specified within model. As presented in Table 8, these parameters include the provincial culling rate, calving rate (i.e., calves produced per cow per year), calf death loss rate and cow death loss rate. These have been updated by using expert opinion from Alberta Agriculture.

5.5 Updating Dairy Demand in the CRAM

In the original version of CRAM seven types of dairy products were specified: fresh milk, low fat milk, cream, cheese, butter, skim milk powder and other dairy products. The decision as to whether to expand the product mix and what product(s) to include depends on factors such as the relative importance of dairy products in terms of consumption, taking into account any changes over time, as well as the availability of data relating to input requirements and processing costs. From current consumption data (Table 17), and production data (Table 2) the category of "dairy product" should include more products such as partly skim milk (i.e., 2% and 1% fluid milk), cheddar cheese, and ice-cream. Data required to update and expand this aspect of the model include prices (CANSIM Matrix 7440 & 2001) and quantities (Statistics Canada 1996b and Statistics Canada 91-002.) as well as demand elasticity estimates (Veeman et al. 1995, and CRAM) for each dairy product.

Dairy demand data are available only at the national level as per capita consumption (Statistics Canada 1998). The quantity demanded for processed dairy products in each province was calculated from the product of the national per capita consumption and the provincial population (Statistics Canada 91-002). The quantity of provincial export shipments was obtained from the Dairy Information Center (http://www.dairyinfo.agr.ca/ Jan. 1998). The provincial dairy product demands are presented in Table 10.

A comparison of the dairy demand data with the dairy product production data in Table 2 reveals that the quantity demanded for fluid dairy products in this table is consistent with the production data at the national level. However, since dairy products can move among provinces, the quantity demanded and quantity produced may not match in each province.

The demand and production data for industrial dairy products are not as consistent as for fluid products at the national level. One possible reason is that CDC storage exists for industrial dairy products such as butter and skim milk powder as discussed in section 2.2. As well, some commercial storage may exist for dairy products such as ice cream. Because the model in this study is a static equilibrium model, demand and supply quantities should be equal. In the empirical model, difference between national dairy production, and national dairy demand is treated as an "export" to (if production exceeds demand) or "import" from (if demand exceeds production) the world market.

The prices of dairy products are calculated by dividing the total dollar value of factor shipment by the quantity of final dairy processed products (Statistics Canada 31-211: *Products shipped by Canadian manufacturers*). Therefore, the price used in the model is the wholesale price from dairy-processing plants. The prices of dairy products are also presented in Table 10.

Estimated demand elasticity values from other studies are obtained and summarized in Table 11. The estimates in Table 11 suggest a wide range of possible elasticities for dairy products in Canada. The elasticities in the current version of CRAM and those estimated by Veeman and Peng (1995) are somewhat consistent with each other. As well, they tend to be in the middle relative to the estimates from the other studies. As the study by Veeman and Peng (1995) present the most detailed and most recent study, their elasticity estimates are used to update most for the demand elasticities of dairy products.[23] A series of sensitivity analyses for the different elasticity values from other studies are performed in order to get the best calibration results for the actual demand data. Sensitivity analysis results suggest that most of the demand elasticities estimated by Veeman and Peng (i.e., low-fat milk, cream, cheddar cheese and milk powder) provide good empirical results that calibrate well to the actual data. However, for some other demand elasticities, the values from other studies may provide better empirical results. These few exceptions include standard milk (keeping the current CRAM value), other cheeses (keeping the current CRAM value) and butter (using Cluff and Stonehouse 1992). The demand elasticities for these products are presented in Table 11.

5.6 Updating Dairy Transportation Activities in CRAM

Transportation costs for diary products are included in the objective function are subtracted from the total welfare measurement. Two types of information are needed to model transportation activities in CRAM: the distance involved and the unit transportation cost.

[23] Since Veeman and Peng (1995) did not provide the demand elasticity for other dairy products, the same value used in the current CRAM has been kept.

In order to obtain the distance associated with each transportation activity, two types of information and data are needed: the spatial linkage between each province and the spatial distance. A matrix of spatial linkages represents the possible physical connections between transportation points. In the CRAM, there is one representative point (or city) for in each province. Theoretically, the dairy products can be shipped between any two provinces. A matrix of distances is used to represent the actual distance between each pair of representative points/or cities. As this information does do not change over time, the same distance matrix used in the current version of CRAM is used in this study.

Different ways can be used to represent the unit transportation cost. The actual rates for different products and routes under consideration can be obtained, but doing so may not be practical or necessary. Stennes et al. (1991) and Rude (1992) simplify the unit transportation costs by specifying a separate unit value for the different types of products. It is more reasonable to specify the alternative unit transportation cost by providing an estimated equation, as used in Ward and Farris (1988) and Lambert (1991). The benefit of using such an approach is that the parameters of this relationship are easy to update. Since the unit cost will change over time due to changes in fuel cost, inflation, etc., estimation equations can be updated easily (Ward and Farris 1988).

Graham et al. (1989) calculate the transportation costs for dairy products by using the following linear formula, which is also used in the current CRAM:

(5.6-1) $$UTC = 1 + 0.03 * X$$

where UTC is unit transportation cost ($/tonne), and X is the distance (kilometer) between two transportation points.

After comparing different types of transportation functional forms for shipping refrigerated products in the eastern United States, Ward and Farris (1988) conclude that the quadratic form provides the best fit for their data. They provide the unit transportation cost function as:

(5.6-2) $UTC=0.7589 + 0.000682* X + (-2.93E-7)* X^2$,

where UTC is the unit transportation cost (i.e., U.S. dollar cost per mile per cwt.) and X is the distance (miles) over which the product is moved.

Since the cost of inter-provincial movement of dairy products is not available, deciding which functional form serves is the best for this study is difficult. However, it is believed that a linear function form cannot adequately capture the differences in transportation costs between long distance and short distance shipments (Ward and Farris 1988). Therefore, the quadratic transportation function form from Ward and Farris is adapted for use in this study.[24]

Their study was carried out in 1988 in the United States. In order to apply this equation to the CRAM, the function needs to be adjusted for inflation, exchange rates, and other rate such as those for distance and weight[25]. The following relationship is used to calculate the transportation costs for industrial dairy products:

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[24] In the sensitivity test comparing these two function forms, the overall empirical results from model are no significant difference between linear and quadratic function form. The unit transportation cost from quadratic function form is slightly larger than the value from linear function in the shorter distance transportation of dairy products.

[25] Also implicit in this use of this relationship is the assumption that the transportation technology has not changed.

(5.6-3) $$UTC=44.727*(0.7589 + 0.000682* X + (-2.93E-7)*X^2)$$ [26]

where UTC is unit transportation cost (i.e., cost per kilometre per tonne) and distance X is measured in kilometres. [27]

In the current CRAM model, raw milk is not allowed to move between provinces. In order to examine its possible inter-provincial movement, a similar transportation cost equation is needed. However, the unit transportation cost for processed products cannot be used for raw milk, since it is normally shipped using different types of trucks than processed products. For "raw" fluid milk, unit transportation costs are based on estimates obtained from an internal study by Alberta Agriculture:

For short distances (< 301 kilometers):

(5.6-4a) $$UTC = 0.70 + 0.0052 * X$$

For long distances (>300 kilometers):

(5.6-4b) $$UTC = 0.86 + 0.0046 * X$$

5.7 Updating Government Intervention Parameters in CRAM

Government intervention in the Canadian dairy sector is extensive. It is impossible to incorporate all government activities in the model. In this study, the model will capture major explicit government activities in the dairy industry such as quantity controls, levies

[26] The exchange rate is 1.2309 Canadian/US in 1988 (CAMSIN Statistics Canada). Other conversion rates include: 1 cwt =0.4404 hectoliter and 1 mile = 1.6 kilometer. Data from Trucking in Canada (Statistics Canada 1988 and 1996) suggest that the trucking transportation cost is stable during this period.

[27] It is reasonable to use the same unit transportation costs for different processed dairy products, as the products would all tend to be shipped using refrigerated container units.

and direct subsidies. Some other government activities such as price setting for raw milk, and the regional milk pooling agreements are incorporated in the model implicitly.

The government's quantity controls for milk marketing are incorporated in constraints 4.4-1g, which include the industrial milk quota restriction and the fluid milk quota restriction for each province. The provincial quota levels for industrial milk are obtained from the CDC annual report and presented in Table 3. Provincial fluid milk production and quota did not change significantly from 1988 to 1995 (Statistics Canada: CAMISM 5650). The value used in the current CRAM is used for this study.

Governments have also intervened in the dairy industry by collecting levies and providing subsidies as discussed in Chapter 2. CRAM includes national-level parameters for levies and subsidies for milk production. Information from the CDC and various provincial marketing boards was used to update these values to reflect 1995 conditions. These are summarized in Table 13.

Table 5. Milk Production Rate and Feed Requirements for Dairy Cows, by Province 1995

	Milk Production	Feed Requirement (tonnes/animal/year)[a]		
Province	Hectoliter/cow	Hay	Barley	Protein
Newfoundland	76.89	4.90	1.251	0.394
Prince Edward Island	61.19	4.96	0.798	0.218
Nova Scotia	71.03	4.99	1.039	0.323
New Brunswick	63.19	4.96	0.849	0.239
Quebec	66.61	4.97	0.933	0.276
Ontario	66.13	4.97	0.919	0.271
Manitoba	59.14	4.95	0.750	0.196
Saskatchewan	55.98	4.94	0.672	0.163
Alberta	82.31	4.70	1.518	0.468
British Columbia	87.35	4.48	1.384	0.952

Note: a: Hay is defined as an alfalfa-grass mixture. Protein is defined as soybean meal for Ontario, Quebec and the Maritime provinces, and is defined as canola meal for other provinces.
Source: Milk production comes from the CDC Annual Report 1996 and records from the Dairy Herd Improvement Association.

Table 6: Average Variable Costs of Milk Production, by Province

Cost Per Hectoliter	P.E.I.	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	Newfoundland[c]	British Columbia[c]
Feeds	9.12	11.42	10.05	7.7	7.64	10.35	10.33	16.9		
Breeding	0.45	0.39	0.51	0.86	0.76	0.63	0.43	0.65		
Vet, Haulage Fees, etc.	2.32	3.03	4.09	3	5.17	5	4.38	5.64		
Machines & Equipment	1.42	1.7	1.87	1.89	1.83	2.42	1.38			
Gas and Oil	0.62	0.89	0.85	0.87	0.79	0.82	0.75	0.64		
Custom Work	0.01	0.04	-0.33	0.55	0.91	1.72	0.86			
Fertiliser	1.26	1.21	1.37	1.42	1.37	0.72	0.65			
Seed and Plants	0.2	0.32	0.3	0.59	0.63	0.3	0.14			
Other	2.96	3.41	2.75	3.74	1.66	2.02	1.94	1.66		
Land And Building Repairs	0.52	0.78	0.69	1.29	1.47	1.12	1.24	2.04		
Property Taxes and Insurance	0.72	0.9	0.79	1.53	1.24	1.07	0.68	0.74		
Hydro and Telephone	0.51	0.87	0.5	0.98	0.77	1.39	1.41	1.17		
Hired Labour	1.64	1.78	1.76	1.23	0.69	0.44	4.04	3.39		
Total	$21.75	$26.74	$25.20	$25.65	$24.93	$28.00	$28.23	$32.83		
total eligible costs[a]	$8.85	$10.72	$10.89	$11.40	$10.70	$11.25	$13.51	$13.53		
1996 Farm Input Price Index	132.8	132.8	132.8	153.9	150.2	136.2	120.9			
1995 Farm Input Price Index	131.9	131.9	131.9	149.5	149.4	124.2	115.9			
1995 Eligible Costs	$8.79	$10.65	$10.82	$11.07	$10.64	$10.26	$12.95	$10.07	$10.08	$10.07
Costs per Cow										
Production per cow (hl)	61.19	71.03	63.19	66.61	66.13	59.14	53.79	82.31	76.89	87.35
Eligible Costs per Cow	$537.86	$756.28	$683.48	$737.64	$703.82	$606.71	$696.65	$828.56	$775.40	$879.29
Protein Cost[b]	$73.09	$108.35	$80.33	$92.60	$90.78	$65.82	$54.51	$156.80	$132.05	$319.26
Total Cost Per Cow	$610.95	$864.64	$763.80	$830.24	$794.60	$672.53	$751.16	$985.36	$907.45	$1,198.55

Source: Canadian Dairy Commission, 1995, 1996; Appleby 1996, and Ontario Dairy Farm Accounting Project 1997

Note: a: Eligible cost categories included in the budget are breeding, transportation, promotion and other fees, veterinary, fuel and oil, 50% of repair costs for machinery, equipment, land and buildings, property taxes and insurance, hydro and telephone, hired labour and other miscellaneous costs.

b: Protein cost is calculated using market prices for soybean meal or Canole meal, and the feed requirement, specified in Table 5.

c: Since no provincial budgets are available for Newfoundland and British Columbia, an average of New Brunswick, Nova Scotia and Prince Edward Island costs are used as a proxy for Newfoundland costs. Alberta costs are used as a proxy for British Columbia costs.

Table 7 Components of Raw Milk, by Province 1995

Province	Butterfat (% per unit of milk)	SNF Component (% per unit of milk)
British Columbia	3.72	8.76
Alberta	3.66	8.91
Saskatchewan	3.62	8.95
Manitoba	3.74	8.95
Ontario	3.96	9.06
Quebec	3.83	8.98
New Brunswick	3.80	8.91
P.E.I.	3.86	8.89
Nova Scotia	3.78	9.00
Newfoundland	3.55	7.86

Source: http://www.dairyinfo.agr.ca/prices3.html May 1998

Table 8. Miscellaneous Dairy Management Parameter Estimates

Parameter Category	Parameter Estimate
Culling Rate (%)	20
Calf Rate (calves/cow/year)	0.896
Calf Death Loss (%)	15
Cow Death Loss (%)	4

Source: Expert opion in Alberta Agriculture

Table 9. Beef Production Parameter Estimates for Dairy Animals (tonnes of beef per animal)

	Dairy Livestock Class			
Province	*Dairy Cows*	*Dairy Heifers*	*Heifer Calves*	*Veal Calves*[a]
Newfoundland	0.266	0.283	0.283	0.054
Prince Edward Island	0.266	0.283	0.283	0.054
Nova Scotia	0.266	0.283	0.283	0.054
New Brunswick	0.266	0.283	0.283	0.054
Quebec	0.258	0.294	0.294	0.054
Ontario	0.263	0.339	0.339	0.091
Manitoba	0.309	0.289	0.289	0.069
Saskatchewan	0.309	0.289	0.289	0.068
Alberta	0.307	0.317	0.317	0.069
British Columbia	0.277	0.275	0.275	0.077

Source: AAFC data

[a] The beef "yield" for veal calves is unchanged from the original CRAM model.

Table 10. Dairy Product Price and Demand Information, 1995

	Population	Milk 3.2%	Milk 2%	Low Fat Milk[a]	Cream	Ice Cream	Cheddar Cheese	Other Cheese[b]	All Butter	Skim Milk Powder	Other Dairy Products[c]
Unit	1000	liter	Liter	liter	liter	Liter	kg	kg	kg	kg	kg
Price ($/unit)		0.962	0.948	0.888	2.58	2.554	6.004	4.630	5.617	3.566	1.77
Consumption (Per Capita)		16.20	48.3	20.55	5.34	11.6	3.74	5.59	2.76	1.08	5
		Total Consumption (unit 1,000,000 liter or kg)[d]									
East	20711	3.36	10.02	4.26	1.11	2.40	77.46	115.77	57.16	22.37	103.56
Newfoundland	579	0.09	0.28	0.12	0.03	0.07	2.17	3.24	1.60	0.63	2.90
Nova Scotia	937	0.15	0.45	0.19	0.05	0.11	3.50	5.24	2.59	1.01	4.69
P.E.I.	136	0.02	0.07	0.03	0.01	0.02	0.51	0.76	0.38	0.15	0.68
New Brunswick	760	0.12	0.37	0.16	0.04	0.09	2.84	4.25	2.10	0.82	3.80
Quebec	7302	1.18	3.53	1.50	0.39	0.85	27.31	40.82	20.15	7.89	36.51
Ontario	10997	1.78	5.32	2.26	0.59	1.28	41.13	61.47	30.35	11.88	54.99
West	8585	1.39	4.15	1.76	0.46	1.00	32.11	47.99	23.69	9.27	42.93
Manitoba	1133	0.18	0.55	0.23	0.06	0.13	4.24	6.33	3.13	1.22	5.67
Saskatchewan	1015	0.16	0.49	0.21	0.05	0.12	3.80	5.67	2.80	1.10	5.08
Alberta	2726	0.44	1.32	0.56	0.15	0.32	10.20	15.24	7.52	2.94	13.63
British Columbia	3711	0.60	1.80	0.76	0.20	0.43	13.88	20.74	10.24	4.01	18.56
Total for Canada	29389	4.76	14.22	6.04	1.57	3.41	109.91	164.28	81.11	31.74	146.95
Export Demand	-	-	-	-	-	0.41	6.019	7.17	6.265	43.781	7.09
Total Demand		4.76	14.22	6.04	1.57	3.82	119.01	171.45	87.38	75.521	154.04

Sources: Statistics Canada 91-002, Statistics Canada, 1996b and download from Dairy Information Centre at http://www.dairyinfo.agr.ca/(Jan, 1998), IPI from CANSIM (Matrix, 2001)

Note:

a: Low fat milk includes 1% milk and skim milk

b: Other cheese includes cottage cheese and processed cheese

c: Other products include yoghurt, buttermilk powder, buttermilk and chocolate milk and whey powder

d: Unit for Fluid Product is million hectoliters, for dairy products is million kilograms.

Table 11. Estimates of Own Price Elasticity for Canadian Dairy Products

		Study Authors				
Product	**Current Model**	Original CRAM	Veeman and Peng	Hassan and Johnson	Al-Zand and Andriamanjay	Cluff and Stonehouse
Fluid Milk	-			0.439	0.208	0.140
Standard Milk	**0.33**	**0.33**	0.590			
Milk 2%	**0.11**					
Low-Fat Milk	**0.11**	0.340	**0.110**			
Cream	**0.51**	0.500	**0.510**			
Ice Cream	**1.01**					
Cheese	-	0.730		0.860	1.001	0.570
Cheddar Cheese	**0.660**		**0.660**			
Other Cheese	**0.660**		1.220			
Cottage Cheese	-		0.210			
Butter	**0.77**	0.800	1.110	1.059	1.077	**0.770**
Skim Milk Powder	**0.460**	0.390	**0.460**			
Other Dairy Products	**1.010**	**1.010**		0.850		

Source: Al-Zand et al. (1988); Cluff and Stonehouse (1992); Hassan and Johnson (1977); Veeman and Peng (1995);

Table 12. Assumed Conversion Rates for Dairy Products

	Fluid Milk 3.5%	Fluid Milk 2%	Low Fat Milk[a]	Cream	Ice Cream	Cheddar Cheese	Other Cheese[b]	Butter	Skim Milk Powder	Other Dairy Products[c]
Conversion Unit	Kg/hl	Kg/hl	Kg/hl	Kg/hl	Kg/Kg	Kg/Kg	Kg/Kg	Kg/Kg	Kg/Kg	Kg/Kg
Butterfat Content	3.6	1.96	0.667	16.6	0.11	0.33	0.17	0.81	0.001	0.06
SNF Contend	8.52	8.72	8.72	7.4	0.3	0.82	0.36	0.012	0.96	0.25

Source:
1. CRAM 1988,
2. Dairy Farm of Canada 1992,
3. USDA Nutrient Database for Standard Reference (Release 12); Downloaded from http://www.cs.princeton.edu/~ah/food/. Nov. 1998

Note:
a: Low fat milk includes 1% milk and skim milk
b: Other cheese includes cottage cheese and processed cheese
c: Other products including yoghurt, buttermilk powder, buttermilk and chocolate milk and whey powder, using weighted average to calculate the content of mixed product.
d. SNF is Solid Not Fat which includes protein, fibre and other no fat materials

Table 13. Assumed Parameters for Government Intervention, 1995

Parameter Category	Value of 1995
Butterfat Subsidy ($/tonne)	1162.28
In Quota Levy ($/tonne)	233.00
Over Quota Levy ($/000 Hectoliter)	31492.90

Source: CDC Annual Report 1995, Dairy Farmers of Ontario 95-96

Chapter 6 Positive Mathematical Programming and Model Validation

6.1 Introduction

One of the concerns in using CRAM is the assumption of "constant costs" for milk production and dairy processing. The unit costs in the model are parameters, implying that marginal cost is constant, an assumption which is somewhat restrictive. Positive Mathematical Programming (PMP) has been incorporated into CRAM previously (Horner et al. 1992) to address a similar limitation for the cropping sector portion of the model. In the current study, PMP is adapted and applied to the dairy block of CRAM.

Positive mathematical programming, or PMP, is a methodology that makes use of observed behavior to infer information about technical or economic relationships underlying the optimization problem. PMP allows observed outcomes to be incorporated as an interior solution to an optimization problem subject only to the real resource constraints. The original purpose of PMP was to calibrate mathematical programming models to the actual observed data. In recent developments, PMP has been also used to recover flexible cost functions from limited data sets (Paris and Howitt 1998). These two features make PMP attractive for use in the current study.

First, several hundred endogenous activities are in CRAM. Using traditional mathematical programming procedures, calibrating the model results to observed outcomes can be difficult. With the help of PMP, the estimated results from the model might be closer to the actual observed data. Second, as noted earlier in section 5.4.2, due to the nature of supply management in the Canadian dairy industry, obtaining information on the marginal costs of both milk production and milk processing is difficult. However, marginal cost information is critical to develop the empirical model for this study.

Although marginal cost information for each province can be obtained by applying a capitalization model (as discussed in Appendix A) for the milk production sector, this information cannot be used directly in this study. Since the feed cost for the dairy sector has already been captured in CRAM by the cost of crop production, this cost will be counted twice if the marginal cost information from the capitalization model is used directly. Thus, the use of a conventional quota value approach cannot result in an appropriate partial marginal cost of milk production.

Due to the vertical nature of the dairy block in CRAM, a similar situation exists for the dairy-processing sector. Since the cost of raw milk production has been captured in the intermediate production sector, the marginal cost of processed dairy products should exclude the raw milk cost. This requirement makes obtaining an appropriate marginal cost for the processed dairy products more difficult. With the application of PMP, it is possible that the partial marginal costs for the dairy farming and dairy-processing sectors can be calculated from the initial average costs, which exclude the feed cost in the case of milk production, and the cost of milk in the cost of dairy processing.

As noted earlier, this chapter introduces and discusses the application of PMP to the dairy block in CRAM. Empirical observations are used to recover marginal costs for milk production and dairy processing. These are then used to improve model calibration by allowing for a more flexible supply response in the model. The PMP results are then also used in model validation for CRAM.

6.2 Historic Development of PMP

Calibrating models to the observed outcomes has long been an integral part of constructing physical and engineering models.[28] Within economics, calibrating is widely used in macroeconomic modeling. Howitt (1995b) notes that the calibration methods for macroeconomic models have stimulated an emerging literature and that these methods are beginning to predominate in the quantitative application of macroeconomics models.

The calibration method has been used informally in agricultural economics research. However, formal calibration procedures had not gained much attention in agricultural economics until the PMP method was applied in some empirical studies and was formally addressed by Howitt (1995a). In agricultural economics, Howitt (1995b) and Ribaudo et al. (1994) have applied the PMP approach to national sector models. PMP has been applied to several policy models in sector, regional, and farm level studies of crop production. A regional PMP model is applied by Hatchett et al. (1991) to assess drainage control policies. Bauer and Kanakoglu (1990) applied the PMP approach to a sector model for policy analysis in Turkey. The PMP procedures are also used for crop

[28] Although the meaning of calibration and model validation is similar, a clear distinction exists between them. Calibration in mathematical modeling is the process of obtaining a parametric model to reflect the actual production history. Validation is the process or act of demonstrating the calibrated model's ability to function as a credible forward estimating tool or system (International Society of Parametric Analysts 1999).

production in the current version of CRAM. Horner et al. (1992) report that PMP increases consistency between actual data and the model solution for the crop sector.

Before Howitt's study in 1995a, PMP was mainly used as a calibration tool to more closely calibrate the mathematical programming model to the actual observed data in the base year. Although PMP was applied mainly to crop production models before 1995, this method can also be applied to the dairy model and improve the results of CRAM. Furthermore, this improvement is not the only reason to apply PMP in this study. In a methodological study, Paris and Howitt (1998) used PMP as a basic method to recover a marginal cost function and develop a Maximum Entropy method to recover the flexible cost function for limited data sets. This use of PMP provides a more attractive reason to apply PMP to this study.

6.3 General Procedure of PMP

Howitt (1995b) defines calibration as " the choice of free parameters in a model... to match the model outcome to the available data base" (p.147). The cornerstone of PMP is that programming models should calibrate against a baseline and use all the possible information in order to do so. However, traditional mathematical programming does not make use of all the information in the base year (e.g., the actual land use or actual output). In this sense, "the PMP approach is unconventional approach in that it employs both programming constraints and "positive" inferences from the base-year crop allocations"(Howitt 1995a p. 329). This ability allows the historical outcome to be incorporated as an interior solution to an optimization problem, subject only to real resource constraints.

Howitt (1995a) illustrates the main procedures of the PMP by using crop production as an example. The model simulates a farmer's decision regarding crop production, assuming profit maximization, subject to a restriction on land. Hawitt's example is adapted here to illustrate the use of PMP in recovering marginal costs of agricultural production.[29] A farm produces two crops, wheat (w) and oats (o), on 500 acres of land. The relevant information for the two crops is provided below:

P_w = \$2.98/bu　　　　P_o = \$2.20/bu

Y_w = 69 bu/ac　　　　Y_o = 65.9 bu/ac

W_w = (\$129.62/ac)/(69 bu/ac) = \$1.88/bu　　　　W_o = (\$109.90/ac)/(69bu/ac) = \$1.67/bu,

where P_i is the price per bushel for crop i, Y_i is the yield for crop i in bushels per acre, and W_i is the cost per bushel for crop i (i=w, o). In the base year, the farm produces 300 acres or 20,700 bushels of wheat, and 200 acres or 13,100 bushels of oats. Can these limited data (i.e., only average cost information) be used to recover the marginal cost of production and to develop a model that is able to calibrate to the actual land used?

To maximize the profit of a producer subject to the total available land resource, a traditional mathematical programming model is formulated as follows:

(6.3-1a)　　$$\text{Max: } (P_w - W_w)*X_w + (P_o - W_o)*X_o,$$

subject to:

(6.3-1b)　　$$X_w/Y_w + X_o/Y_o \leq L,$$

[29] Howitt (1995a) uses this example to illustrate the use of PMP in recovering a yield function, assuming constant unit costs.

where X_w is the production of wheat and X_o is the production of oats, both in bushels; and L is the total land available. All other parameters are defined as before. Using data from Howitt's example, the numerical model is:

(6.3-1c) Maximize: $(2.98 - 1.88)*X_w + (2.20 - 1.67)*X_o$,

subject to:

(6.3-1d) $(1/69)*X_w + (1/65.9)*X_o \leq 500$

The optimal solution for this model is to grow only wheat (i.e., 500 acres or 34,500 bushels). This solution does not accurately reflect the actual observed behavior; that is, the model is not well calibrated.

If only the average costs of production are available, researchers will normally claim that more information such as the marginal cost of production may be required to obtain accurate empirical results. This requirement may involve the use of the econometric methods to estimate the marginal cost and will result in more data collection. Alternatively, some simplification may apply to treat the average cost of production as the marginal cost. However, the valuable data related to actual land usage are normally not used in the model.

Howitt (1995a) shows that if it is assumed that the objective of the crop farmer is profit maximization and that observed behavior in the base year is optimal, then the observed land use in the base year can be used to derive, adjust or recover some parameters (e.g., the marginal variable cost) in the model. This is accomplished through a three stage PMP process, which involves calibrating marginal cost functions against base data for prices, costs, and yields in order to provide a more flexible marginal cost function (i.e., non-constant) in the mathematical programming model.

In the first stage, a constrained Linear Programming (LP) model with average cost of production is defined to maximize the farmer's profit.

(6.3-2a) $$\text{Max: } (2.98-1.88)*X_w + (2.20-1.67)*X_o,$$

subject to:

(6.3-2b) $$X_w/69 + X_o/65.9 \leq 500$$

(6.3-2c) $$X_w/69 \leq 300 + \varepsilon$$

(6.3-2d) $$X_o/65.9 \leq 200 + \varepsilon,$$

where ε is a small positive number, and all other variables are detailed as before. Compared with the traditional LP model, a calibration constraint of actual land usage with a small positive perturbation ε is added for each crop (i.e., 6.3-2c and 6.3-2d). In the calibration constraint equations, the land used should be less than or equal to the actual land usage plus a positive perturbation.

If the extra calibration constraints (with $\varepsilon = 0.01$) are added, the model can generate results very close to the observed land usage. In the example provided by Howitt, the model can calibrate almost exactly to the actual output (X_w=20701, X_o=13179). However, this model is too restrictive to be used in actual empirical analysis because of the extra calibration constraints. Nonetheless, the information generated by the solution to this model can be used to develop a less restrictive but well calibrated model, in the second stage of PMP.

Howitt (1995a) shows and proves that the dual value associated with the binding resource can be treated as the value of the marginal product for the constraining resources, or the opportunity cost of the resources. This finding is consistent with the principle of opportunity cost in which the marginal net return from a unit increase in the constrained resource determines its opportunity cost. A more flexible marginal cost curve can be derived based on the value of this marginal product. In this example, the average gross margin for wheat is \$1.10/bu (i.e., \$2.98 - \$1.88) and for oats is \$0.53/bu (i.e., \$2.20 - \$1.67). In the stage 1 problem, the oat calibration constraint is slack since the wheat has a high cross marginal value. Therefore, the dual value of resource constraint (6.3-2c) is λ = 1.1-0.53=\$0.57/bu.[30] In microeconomics theory, for a traditional profit maximum problem (e.g. equation 6.3-1), the marginal cost to produce the product is equal to the marginal revenue minus the dual value of the fixed resource constraint. Thus, the marginal cost of wheat (i.e., MC_w) in this example is equal to 2.98-0.57=\$2.41/bu at the production level observed in the base year. This marginal cost can be used to uniquely derive the calibrating marginal cost function parameters (i.e., the slope and intercept, assuming a linear marginal cost function).

A linear marginal cost function for wheat may be represented as

(6.3-3a) $$MC = \alpha + \beta . X,$$

where α and β are, respectively, the intercept and slope. With profit maximization as an assumption, the marginal cost function may also be interpreted as the supply function.

[30] This is consistent with Howitt's (1995a) result. The only difference is the unit of the measurement: \$0.57 per bushel versus \$41 per acre (with production of 69 bushels per acre).

The marginal cost here is price as a function of quantity. From this "supply function," we have $\beta = \partial\, MC/\partial X$.

In order to obtain the parameters for this marginal cost function, the supply elasticity,

(6.3-3b) $\varepsilon_s = (\partial X/\partial p).(p/X)$,

is also required. For the optimal solution, the product price (P) is assumed to be equal to the marginal cost (MC), the quantity X equal to the solution of first step; therefore,

(6.3-3c) $\beta = MC/\varepsilon_s X$.

After β is derived, the intercept α is calculated as

(6.3-3d) $\alpha = \beta.X - P = (MC/\varepsilon_s X).X - MC = MC(1 - 1/\varepsilon_s)$

For simplicity, it is assumed that ε_s equals to 1.0. Then for wheat, the intercept of the marginal cost function (α) is the origin and

(6.3-3e) $\beta = 2.41/(1*20701) = 0.0001164$

The marginal cost for wheat is therefore

(6.3-3f) $MC_w = 0.001164*X_w$.

Assuming no fixed costs, total cost (TC_w) for wheat is equal to the integral of MC_w

(6.3-3g) $TC_w = 0.000058*X_w^2$,

that the profit function for wheat is

(6.3-3h) $PXw\text{-}TCw = PXw - \int(\alpha + \beta Xw)dx = 2.98Xw - 0.000058Xw^2$

Using a similar approach,

(6.3-4a) $MC_o = (2.2\text{-}0.84)/13179 = 0.000103$,

the marginal cost curve for oats is MC_o=0.0000063X_o, and the profit function for oats is

(6.3-4b) $$PX_o\text{-}TC_o = PX_o - \int(\alpha + \beta X_o)dx = 2.20X_o - 0.000052X_o^2.$$

In the third stage of PMP, the extra calibration constraints are removed, and the derived marginal cost functions from stage two are used with the base-year data to specify the PMP model.

(6.3-5a) $$\text{Max } 2.98Xw - 0.000058Xw^2 + 2.20Xo - 0.000052Xo^2,$$

subject to

(6.3-5b) $$Xw/69 + Xo/65.9 \leq 500$$

Although the extra calibration constraints of actual land usage are no longer present, the information associated with these calibration constraints is captured through the new non-linear objective function, which comes from the second stage of PMP. Using the above numerical example, the resulting PMP model can calibrate to acreage allocation, input usage, and the objective function value.

The example discussed above focuses on the marginal cost curve, while the application of CRAM focuses on improving the supply response. However, a connection exists because the marginal cost is the supply response function under the assumption of profit maximum for the price taking firm. Moreover, the process as discussed in the simple example is not the only way to apply PMP, for it can be carried out by alternative methods. The above example is slightly different from Howitt's (1995a) example, in which a production function is "recovered". The analysis in CRAM for crop costs is also done by using a slightly different approach (i.e., by assuming "symmetry" in Horner et al. 1992).

The PMP process used in this chapter to derive the milk production and the dairy processing supply functions similar as that in the above example in that supply elasticities and appropriate constraint dual values for the implied opportunity costs are used to derive marginal cost functions. These functions are then interpreted as supply functions for use in policy analysis.

6.4 Application of PMP to the Dairy Block in CRAM

As noted earlier, PMP is applied in the current study to recover the marginal costs for milk production and dairy processing. These marginal cost relationships (i.e., functions of quantity produced) are then used to represent supply response functions for these products in order to have a more flexible and "valid" model for use in the policy analysis. Due to the differences between dairy production and crop production, as incorporated in CRAM, the PMP method as presented by Howitt (1995a) and illustrated in the previous example cannot be applied directly to the dairy sector. For example, in CRAM, total land is fixed for crop production, while for the dairy sector, the milk marketing quota is fixed, and the number of cows can be adjusted according to the quota level. Another difference is that the structure of the sectors as incorporated in CRAM are not the same. Crop production is incorporated to the "farm gate" only, while the dairy sector within CRAM has multiple stages of production. Therefore, it is a challenge to extend the PMP method described by Howitt (1995a) to a multi-level, hedonic spatial equilibrium dairy model under supply management environment such as the Canadian dairy industry.

In the dairy sector, the dairy demand, production, processing and technical transformation relationships for each product are required to determine levels of milk production, final product processing, and the final market price. In implementing PMP, it is assumed that all individuals involved in the sector (i.e., producers, processors and consumers) behave "rationally" (i.e., their behavior is consistent with standard economic theory of the consumer and producer). Observed market behavior can then be used to derive or recover underlying economic relationships; specifically, partial marginal cost parameters for milk production and dairy processing.

Compared with the simplified crop production example in Howitt's presentation, the multi-level spatial equilibrium model is more complicated in terms of choosing the "right" variables to be calibrated. In a sense, no absolute right or wrong choice of calibrated variables can be made. For example, in a crop production model, land allocation is normally used as the calibrated variable. However, the quantity of crop production serves the same function if these data are more reliable. Since more than one market level is modeled in the dairy block of CRAM, relevant variables in the model include both milk production activities and dairy processing activities. However, calibrating results to one set of variables does not guarantee that the other set will accurately calibrate as well.[31]

In this study, efforts were made to choose as many variables as possible in the different market levels to improve overall modeling results. Ideally, if perfect reliable

[31] Evidence from experimentation with the dairy block of CRAM supports this statement. In particular, if dairy product demand is used to calibrate the model, the milk production and dairy processing levels do not calibrate accurately. Conversely, if milk production variables are used to calibrate the model, dairy demand does not "calibrate."

data sets are available for use in modeling, a researcher can select all of the relevant variables to be calibrated to the actual data and get "perfect" results. However, from empirical experience, only a subset of the potential candidates can be chosen. Otherwise, the empirical model does not converge due to being overly constrained.

At the farm level, the quantity of milk production for each province is used as the calibrating variable. At the processing level, the model has two sets of possible calibrating variables: production of processed dairy products and the final demand for processed dairy products. Since the final products can be transferred between provinces in the spatial model, the production in each province is potentially different from the final demand in that province. The results of empirical experimentation[32] suggest that only one calibrating variable for final dairy products can be chosen: either the quantity of demand or the quantity of supply for processed dairy products. Since the quantity of milk production for each province is already used as the calibrating variable for the milk production level, demand quantities are chosen as the calibration base for the dairy processing level of the model.[33]

The PMP calibration approach developed in this study uses a three-stage process similar to the one suggested by Howitt (1995a). The first step is to define a mathematical programming SPE model, based on the original model (*4.4-1*). This SPE model includes a simplified producer surplus (using average cost) with extra calibration constraints in order to calibrate the model to the base year observations and to derive a marginal cost

[32] Several possible combinations of calibrating variables (i.e., dairy product demand and supply, and milk production) were tested to determine the best empirical results. If all of the possible variables were chosen to be calibrated, the model did not converge to a solution.

[33] It is also possible to use the quantities of supply as the calibration variables.

vector. A simplified mathematical programming specification is necessary during the first stage to exploit the available information by using a minimal set of assumptions (Howitt 1995a). The model takes on the following specification:

(6.4-1a) $$\text{Max: } \sum_{n,j}\int_0^{D_{n,j}} P^d_{n,j}(x)dx \; - \sum_{m,i} AC_{1mi}\, S_{m,i} - \sum_{m,n,i,j} AC_{2n,i}\, S_{n,i}$$

$$- \sum_{m,i,j} X_{m,i,j}\, t_{m,i,j} - \sum_{n,i,j} X_{n,i,j}\, t_{n,i,j}$$

s.t.

(6.4-1b) $$S_{m,i} \geq \sum_j X_{j,m,i,}$$

(6.4-1c) $$\sum_i X_{i,m,j} \geq D_{m,j}$$

(6.4-1d) $$S_{n,i} \geq \sum_j X_{j,n,i,}$$

(6.4-1e) $$\sum_i X_{i,n,j} \geq D_{n,j}$$

(6.4-1f) $$\sum_m D_{m,j}\, a_{m,j,s} \geq \sum_n S_{n,i}\, b_{n,i,s}$$

(6.4-1g) $$Q_{m,i} \geq S_{m,i}$$

(6.4-1h) $$PMPD_{n,j} + \varepsilon \geq D_{n,j}$$

(6.4-1i) $$PMPS_{m,i} + \varepsilon \geq S_{m,i}$$

$$S_{m,i} \geq 0,\; D_{m,j} \geq 0,\; S_{n,i} \geq 0,\; D_{n,j} \geq 0,\; X_{n,i,j} \geq 0,\; t_{n,i,j} \geq 0,$$

where AC_{1mi} is the average cost of raw milk commodity m in region i, and $AC_{2n,i}$ is the average cost of processed dairy product n in region i. $PMPD_{n,j}$ is the observed demand for dairy product n in region i and $PMPS_{m,i}$ is actual milk production for each province i, and ε is an arbitrarily small positive number (i.e., 0.01 in the model). Other notation retains the same meaning as defined in the Chapter 4 (equation *4.4-1)*.

Compared with the original model (*4.4-1*), the revised PMP model has two additional sets of constraints; specifically, the PMP calibration constraints (6.4-1i) and (6.4-1h). These constraints, which are normally not used directly in traditional mathematical programming, are the key component for PMP. These equations force the simplified PMP non-linear model to calibrate to the actual observed data (i.e., $PMPD_{n,j}$ and $PMPS_{m,i}$). The positive perturbation on the calibration constraints ensures that the dual values on the allocable resources represent the marginal values of the resource constraints. The most important step in the first stage is to "fine tune" the model in order to obtain reasonable results and dual values for the constraints.

In the second stage, the dual values chosen from the first stage are used to recover a non-linear objective function that is used in the third stage of PMP. For the partial marginal cost of processed dairy products (defined as MC_{ni}), the shadow value of the calibration constraint cannot be used directly, since this shadow value is the total marginal value of the dairy products. Otherwise, the partial marginal cost of dairy processed products will be the total marginal cost, and the value will be too high. Therefore, the marginal cost information must be derived from other dual values.

The shadow value for the dairy products market balance constraint (6.4-1e) is another candidate.[34] These constraints ensure that, in each province, the sum of dairy product consumption and provincial dairy product exports (or shipments) is less than or equal to the sum of dairy production and dairy product imports (or shipments) in that province. At the optimal solution, the shadow value of this constraint is equal to the marginal value or the marginal cost of the final commodity $S_{n,i}$. From an empirical point of view, the magnitudes of this dual value are in the range of the actual data – the partial average cost of the dairy products. The marginal cost of processed dairy products MC_{ni} is set equal to the dual value of the market supply constraint (6.4-1e).

Following Howitt's presentation, the dual values of the calibration constraint (6.4-1i) are used to obtain the marginal cost of raw milk (defined as MC_{mi}). The dual value of this resource constraint is equal to the marginal cost of milk production. In CRAM, the marginal cost of milk production MC_{mi} is actually converted to a marginal cost per dairy cow instead of per hectoliter of raw milk by multiplying the MC_{mi} by the annual milk production per cow.

After obtaining the marginal costs, an upward sloping supply function can be recovered for both milk production and dairy processing. Since the procedure used for

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[34] Using the shadow value from equation *(4.4-2a)* is one option to obtain the marginal cost (i.e., from the difference between the total marginal revenue and the sum of the dual values of raw milk). However, marginal costs calculated from this method are relatively high compared with average cost data. One possible reason for this result is that due to the multi-production structure, partial marginal costs of dairy products that exclude the feed cost are required in the model. Since the dual value of milk here is the partial dual value (excluding the feed cost), the difference between total marginal revenue and the sum of the partial dual values of hedonic characteristics for raw milk (i.e., butter fat and SNF) will include the cost of feed and, therefore, marginal costs are relatively high. Therefore, this method is not suitable.

both milk production and dairy processing is the same, the same example may be used to illustrate the derivation for both levels, as follows:

(6.4-2a) $$P^s = \alpha + \beta Q^s$$

The slope of the supply function, β, can be obtained by using the marginal cost from the PMP procedure:

(6.4-2b) $$\beta = MC/\varepsilon_s Q^*$$

where *MC* is the marginal cost of production, Q* is the actual equilibrium i.e., observed supply quantity in the base year, and ε_s is the supply elasticity. The intercept of the supply function α can be obtained as follows:

(6.4-2c) $$\alpha = MC(1 - 1/\varepsilon_s),$$

where *MC* and ε_s are defined as before.

In the third stage, the two sets of calibration constraints (i.e., 6.4-1h and 6.4-1i) are removed from the model. The recovered upward sloping supply functions are used to replace the simplified average cost of milk production and dairy processing in the objective function. In this way, the revised CRAM more closely resembles the empirical model as described in section 4.3.

6.5 Model Validation and Sensitivity Analysis

The PMP approach is carried out by using the General Algebraic Modeling System (GAMS v2.25) mathematical program computer package. GAMS is designed for modeling linear, nonlinear, and mixed integer optimization problems to solve large complex models related to policy analysis and decision making (Brook et al. 1996). The results from each stage can be saved and used as the starting point for the next stage. After the three stage process, the PMP results are obtained. These results represent the "baseline" for the analysis in this study and are presented in the rest of this chapter (from Table 14 to Table 28). The results are used to validate the use of CRAM as an appropriate model for this study, and to test the sensitivity of the baseline to changes in key parameters.

6.5.1 Model Validation

Model validation involves how well the model simulates the real world. The validation process can provide valuable insights into the behavior of the model and the interpretation of model results. It can also help determine the usefulness of the model for its intended applications and the range of applications for which the model is valid (McCarl and Apland 1986). Model validation is typically carried out through a series of comparisons between model results and observed values of particular variables. Following Hazell and Norton (1986), several comparisons and tests are carried out to validate the model in this study; a capacity test, a marginal cost test, an input levels test, and an output levels test.

The first test is a capacity test, which is to used verify whether the constraints of the model allow for observed production or demand levels for all of the products. A capacity test examines the model's "feasibility" of being able to replicate observed values, but does not examine the model's ability to actually generate those values. The test is usually implemented by adding constraints to test if the model can produce or sell at least as much as the observed base-year output of each product. In this study, a similar test is implemented (as described in constraint 6.4-1h). As described earlier, the first stage of PMP is carried out by restricting production and consumption of dairy products to no more than 101 percent of 1995 levels. The results (Table 16) show that all the dairy products in the model can produce at least as much as the observed base-year data. While this process is not equivalent to running a capacity test on the model, the results suggest that the model would "pass" the capacity test.

The second test used to validate the model is a marginal cost test. This test examines if the marginal costs of production are equal to the output price. In order to carry out this test, Hazell and Norton (1986) suggest that the production of each commodity be constrained to a level at least as great as it had in the base period. Again, the results from the first stage of PMP are used to confirm that the model satisfied the test. At the optimal solution of the mathematical programming model, the marginal cost estimate of dairy products are equal to the equilibrium price estimates calculated from the model.[35] As actual prices of dairy products are available only at the national level, the provincial equilibrium prices of dairy processed products obtained from the solution of the first stage of the PMP model are averaged in order to make the comparison. The test results are presented in Table 17. The marginal costs for all the dairy products are very close to the actual manufacturing price estimate. The maximum difference between the actual and predicted price is less than 0.28%.

[35] Please note that the marginal costs here are the total marginal costs, since it is the predicted price calculated from the model.

Since one of the important purposes for using PMP in this study is to generate the partial marginal costs from average cost information, further validation for the marginal costs is provided here. Table 18 provides a comparison of the average cost estimates used to initiate the PMP process, the partial marginal cost estimates from PMP and the total marginal cost estimates resulting from the capitalization approach using quota values. The range of partial marginal costs is relatively close to the average partial cost for most of the provinces. In general, the partial marginal costs are slightly greater than the average costs. From the survey data, the partial average cost per dairy cow in Ontario is lower than that in the Quebec. However, from the capitalization model using quota values, Ontario has higher marginal costs than Quebec. Although PMP initially uses the average costs, after the PMP process, the model recovers a marginal cost pattern for Ontario and Quebec that is consistent with the capitalization model marginal cost estimates.

The marginal cost estimates for dairy processed products are presented in Table 19. Since no similar study for the marginal cost of processed products has been done at a provincial level, no comparisons can be made with the results of other studies. If compared with the partial average cost estimates, the PMP results provide a similar pattern of partial marginal costs for ten dairy products in ten different provinces. The estimated marginal cost of industrial products is relatively consistent among provinces; that is, the differences between any two provinces are small. However, the marginal cost estimates for fluid products vary across provinces because of the restrictions placed on inter-provincial transportation for different dairy products in CRAM. Industrial dairy products are allowed in CRAM to move between provinces, whereas fluid products are not. Therefore, the difference in the marginal cost for industrial products among the provinces is smaller than that for the marginal costs of fluid dairy products. Consistent with raw milk production, Ontario has higher marginal cost estimates than Quebec for most processed dairy products.

The third test of model validation involves the input levels. This test involves a comparison of the model's solution in terms of input levels, with actual inputs used. In this study, the test compares the input of raw milk for dairy processing, and dairy cows used for milk production, with actual data from each province (Table 1). Table 20 shows that the output of fluid milk from the model is the same as the actual data for most provinces with the exception of Quebec (-5%), Ontario (-10%) and Alberta (-4.1%). For industrial milk production (including industrial cream), only Alberta and Quebec have lower (11% and 3%, respectively) solution values than actual data, whereas all other provinces calibrate exactly to the data. The dairy cow numbers used in each province are presented in Table 21. The predicted numbers of cow used are lower than the actual data for each province. At the national level, the total predicted number of cows is 10% (or 130,000 head) less than the data would suggest. However, this deviation is not surprising and does not mean the model does not have good calibration. The pattern of the results versus the data shows that the ranking of provinces is identical. The actual dairy cow numbers for each province come from *Livestock Statistics* (Statistics Canada 1996a). These statistics represent the total dairy cow numbers in Canada, including those used for commercial and non-commercial purposes. However, the intent here is to model production by commercial dairy farmers. Therefore, it is not unexpected that CRAM predicts lower cow numbers than those provided by Statistics Canada.

The fourth test used is an output level test. The test compares the model's baseline production level with the actual production data for that period. For this study, the model incorporates two levels of production: dairy farming and dairy processing. This test can be conducted for CRAM by comparing the actual provincial production of raw milk and processed dairy products with the simulated results. As the raw milk output of the dairy farming sector is the input for the dairy-processing sector, this test has been done already, as discussed in the above paragraph.

Since the quantity of dairy product consumption and production should match under equilibrium condition, the output test for the second level of production (i.e., processed dairy products) can be done by comparing the baseline solution with either dairy product consumption data or production data. The comparison for the demand data is presented in Table 15. The model calibrates very well to the actual demand data at the national level. The difference between the base year and the PMP model ranges from -4.2% to 16.9%. Before applying PMP, the difference in the demand quantity between the base year and the CRAM results (i.e., running CRAM using the initial average costs) ranges from -27% to 56%. The model solution and actual dairy production data are summarized in Table 22. It should be noted that although in the models most dairy products are produced in each province, only some of these products can be compared with the actual observed data because some output observations are not available from the original data sources.[36] As shown in Table 22, the solutions for the two large dairy product producers (i.e., Ontario and Quebec) are close to the actual data. Most of deviations in these two provinces are below 12%.[37]

In general, fluid milk products tend to calibrate much better than the industrial dairy products. These differences result from variations in the accuracy of data. The model requires that the quantity demanded be equal to the quantity supplied. The quantity of demand and supply for fluid dairy products matches well in the available data, due to the perishable nature of these products. However, because of the storage of industrial dairy products, the demand and supply quantities do not necessarily match in any particular period, as is assumed by a static model such as CRAM.

The model in this study passes most of the validation tests as suggested by Hazell and Norton. However, some deviations of the baseline solution from actual data are present, due to the following sources:

- No consumption data are available at the provincial level. Therefore, all per capita consumption in the model is assumed to be the same across provinces.
- Limited data are available for inputs and outputs of final dairy products in each province.
- Different time periods for data are used from different sources. Most milk production data are given in terms of a dairy year (i.e., July to August). However, some demand

[36] For example, although the output of dairy products is available for some provinces (e.g., Ontario, Quebec, and Alberta) from Statistics Canada, for most of the small provinces, these data are not available due to confidentiality reasons.

[37] The exception is the output of ice cream, other cheese, and milk powder in Quebec.

and production data for final dairy products are available on a calendar year basis only.

Although no consensus exists on what are acceptable percentage differences, Hazell and Norton (1986) note that a percentage difference "of 5% would be exceptional, below 10% is good, and of 15% or more indicates that the model may need improvement" (p. 271). From the above validation test results, it can be concluded that, after applying PMP, CRAM appears to be valid for use in this study and seems to provide a good representation of the Canadian dairy sector.

6.6 Conclusion

The PMP methodology provides an alternative way to obtain marginal costs for use in modeling a complex multi-level market structure. The magnitudes of the marginal cost are reasonable in term of their range and are comparable to the results obtained from other methods or sources. Most importantly, the marginal costs obtained from the PMP process can improve the empirical results significantly.

The revised CRAM, including the PMP results, is used to analyze alternative policy scenarios for inter-provincial trade liberalization in the Canadian dairy sector. The results for these scenarios are presented and discussed in the following chapter.

Table 14. Baseline Model Results (partial[a])

Province	*Dairy Cow Number*	*Fluid Milk Production*	*Industrial Milk Production*	*Partial Marginal Cost of Butter*	*Dairy Output Butter*	*Welfare Consumer Surplus*	*Welfare Dairy Farm*	*Welfare Dairy Process.*	*Welfare Total*
	1,000 Head	million Hectoliter	million Hectoliter	$/kg	1,000 Tonne	1000 Dollar	1000 Dollar	1000 Dollar	1000 Dollar
British Columbia	78	3.652	1.802	2.251	5.765	2309897	45960.76	98548.92	2454407
Alberta	98	2.964	3.393	2.203	8.301	1696788	45683.25	81614.05	1824085
Saskatchewan	44	1.156	1.17	2.203	2.528	631782.7	20358.32	32996.57	685137.6
Manitoba	56	1.243	1.778	2.204	3.512	705231.3	23318.41	42116.58	770666.3
Ontario	421	11.688	14.157	2.192	34.403	6547951	195913.3	361807.3	7105671
Quebec	507	7.045	22.581	2.177	37.894	4347834	242309.4	371527.7	4961672
New Brunswick	22.3	0.691	0.468	2.232	1.485	452527.3	9094.00	18469.21	480090.5
P.E.I.	18.3	0.21	0.819	2.213	1.316	80978.56	8604.96	15222.95	104806.5
Nova Scotia	26.9	1.075	0.632	2.230	2.023	557918.5	11191.96	27658.09	596768.5
Newfoundland	4.5	0.297		2.224	0.003	344754.3	2016.74	4702.14	351473.2
Canada	1276	30.021	46.8		84.64	998998.5	604451.2	1054663	1.93E+07

a. For more results of dairy processed products please refer to Table 22 and Table 25

Table 15. Calibration to Demand Data with/without the PMP method

	Baseline Solution	Calibration Data	Difference	% Difference
	Without PMP Methodology			
Canadian Consumption				
3.5% Milk	4.85	4.76	0.09	1.98
2% Milk	14.37	14.22	0.15	1.03
Low Fat Milk[a]	6.10	6.04	0.06	1.01
Cream	1.79	1.57	0.23	14.39
Ice Cream	349.57	300.84	48.73	16.20
Cheddar Cheese	114.41	109.57	4.84	4.42
Other Cheese	198.00	163.76	34.25	20.91
Butter	88.20	80.85	7.44	9.21
Skim Milk Powder	28.33	29.69	-1.35	-4.56
Other Dairy Products	170.70	146.49	24.22	16.53
Exports				
Ice Cream	29.91	41.00	-11.08	-27.04
Cheddar Cheese	7.20	6.019	1.186	19.71
Other Cheese	49.40	32.17	17.23	53.58
Butter	13.74	11.93	1.81	15.15
Milk Powder	51.56	43.78	7.78	17.78
Other Dairy Products	11.10	7.09	4.01	56.53
	With the PMP methodology			
Canadian Consumption				
3.5% Milk	4.81	4.76	0.05	1.11
2% Milk	14.34	14.22	0.12	0.87
Low Fat Milk	6.10	6.04	0.07	1.09
Cream	1.75	1.57	0.18	11.67
Ice Cream	324.24	300.84	23.40	7.78
Cheddar Cheese	113.66	109.57	4.09	3.73
Other Cheese	190.39	163.76	26.63	16.26
Butter	84.64	80.85	3.79	4.68
Skim Milk Powder	29.04	29.69	-0.65	-2.19
Other Dairy Products	171.26	146.49	24.77	16.91
Exports				
Ice Cream	45.21	41.00	4.207	10.26
Cheddar Cheese	6.31	6.02	0.2	4.89
Other Cheese	37.06	32.17	4.90	15.24
Butter	12.59	11.93	0.68	5.52
Skim Milk Powder	41.96	43.78	-1.82	-4.16
Other Dairy Products	7.68	7.09	0.59	8.24

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
& 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

a: Low Fat Milk includes 1% milk and skim milk.

Table 16. Model Validation: Capacity Test

	Capacity Test Results	Calibration Data	Difference	Percentage Difference
Canadian Consumption				
3.5% Milk	4.765	4.76	0.005	0.10%
2% Milk	14.234	14.22	0.014	0.10%
Low Milk	6.046	6.04	0.006	0.10%
Cream	1.572	1.57	0.002	0.10%
Ice Cream	340.34	340	0.34	0.10%
Cheddar Cheese	109.68	109.57	0.11	0.10%
Other Cheese	163.924	163.76	0.164	0.10%
Butter	80.931	80.85	0.081	0.10%
Skim Milk Powder	31.672	31.64	0.032	0.10%
Other Dairy Products	146.636	146.49	0.146	0.10%
Export				
Ice Cream	41.161	41.12	0.041	0.10%
Cheddar Cheese	6.025	6.019	0.006	0.10%
Other Cheese	7.174	7.166	0.007	0.10%
Butter	6.271	6.265	0.006	0.10%
Skim Milk Powder	43.824	43.78	0.044	0.10%
Other Dairy Products	7.101	7.094	0.007	0.10%

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
& 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Powder and Other Dairy Products)

Table 17. Model Validation: Marginal Cost Test

	Model Solution	Calibration Data	Difference	Percentage Difference
3.5% Milk	0.960	0.962	-0.00171	-0.18%
2% Milk	0.946	0.948	-0.00174	-0.18%
1% or Lower milk	0.886	0.888	-0.00230	-0.26%
Cream	2.573	2.58	-0.00734	-0.28%
Ice Cream	2.554	2.554	0.000247	0.01%
Cheddar Cheese	6.004	6.004	-0.000200	0.00%
Other Cheese	4.630	4.63	0.000303	0.01%
Butter	5.616	5.617	-0.001	-0.02%
Skim Powder	3.565	3.566	-0.00059	-0.02%
Other Dairy Products	1.770	1.77	5.8E-05	0.00%

Unit: $/liter for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
$/kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Powder and Other Product)

Table 18. Estimates for the Cost of Milk Production: Average, Partial and Total Marginal Costs ($/cow) by Province

	Partial Average Cost based on Survey	Partial Marginal Cost from Positive Math. Programming	Total Marginal Cost From Capital Pricing Model[a]
Newfoundland	907.45	1055.906	3306.27
Nova Scotia	864.64	!008.248	2486.05
P.E.I.	610.95	1009.613	2141.65
New Brunswick	763.8	1013.408	2717.17
Queue	830.24	1001.717	1998.3
Ontario	794.6	1345.398	2380.68
Manitoba	672.52	970.066	2365.6
Saskatchewan	751.16	952.376	2239.2
Alberta	985.36	1068.51	3292.4
British Columbia	1198.55	1027.33	3843.4

a. The estimation procedure for these marginal costs is described in Appendix A.

Table 19. Average and Marginal Processing Cost Estimates for Dairy Products (Excluding Raw Milk), 1995

	Fluid Milk 3.5% ($/liter)	Fluid Milk 2% ($/liter)	Fluid Milk 1% &Skim ($/liter)	Cream ($/kg)	Ice Cream ($/kg)	Other Cheese ($/kg)	Cheddar Cheese ($/kg)	Butter ($/kg)	Skim Milk Powder ($/kg)	Other Dairy Products ($/kg)
	Average Processing Cost Estimates									
British Columbia	0.340	0.340	0.310	0.910	0.900	1.640	-	-	-	0.630
Alberta	0.240	0.230	0.220	0.630	0.620	1.130	1.470	1.370	-	0.430
Saskatchewan	-	-	-	-	-	-	-	-	-	-
Manitoba	0.210	0.200	0.190	0.560	0.550	-	1.290	1.210	-	0.380
Ontario	0.330	0.320	0.300	0.870	0.860	1.570	2.030	1.900	1.210	0.600
Quebec	0.290	0.290	0.270	0.780	0.770	1.400	1.820	1.700	1.080	0.540
New Brunswick	-	-	-	-	-	-	-	-	-	-
P.E.I.	-	-	-	-	-	-	-	-	-	-
Nova Scotia										
Newfoundland										
	Marginal Processing Costs from the PMP Model									
British Columbia	0.466	0.463	0.441	1.030	1.320	3.229	2.129	2.251	2.397	0.915
Alberta	0.356	0.355	0.341	0.736	1.303	3.179	2.146	2.203	2.362	0.906
Saskatchewan	0.312	0.339	0.298	0.646	1.305	3.200	2.158	2.203	2.386	0.902
Manitoba	0.329	0.329	0.316	0.661	1.310	3.212	2.155	2.204	2.401	0.851
Ontario	0.331	0.329	0.329	0.981	1.315	3.205	2.106	2.192	2.419	0.856
Quebec	0.323	0.325	0.323	0.939	1.269	3.155	2.056	2.177	2.401	0.906
New Brunswick	0.420	0.418	0.400	0.898	1.298	3.210	2.077	2.232	2.430	0.911
P.E.I.	0.415	0.414	0.396	0.891	1.282	3.210	2.111	2.213	2.416	0.899
Nova Scotia	0.417	0.415	0.397	0.895	1.287	3.207	2.108	2.230	2.411	0.894
Newfoundland	0.452	0.451	0.433	0.925	1.293	3.201	2.102	2.224	2.405	0.888

Source: 1. The information about total variable cost is obtained from Industry Division, Statistics Canada.
2. Cost share calculated from Statistic Canada (catalogue 23-001-QXPB and catalogue 31-203-XPB). Refer to section 5.4.4.

Table 20. Model Validation: Raw Milk Production Test

Province	Data	Baseline	Difference	%difference
	Fluid Milk Quantity (million Hectoliter)			
British Columbia	3.652	3.652	0.000	0.00
Alberta	2.840	2.964	-0.124	-4.20
Saskatchewan	1.156	1.156	0.000	0.00
Manitoba	1.243	1.243	0.000	0.00
Ontario	10.483	11.688	-1.204	-10.31
Quebec	6.691	7.045	-0.354	-5.02
New Brunswick	0.691	0.691	0.000	0.00
P.E.I.	0.210	0.210	0.000	0.00
Nova Scotia	1.075	1.075	0.000	0.00
Newfoundland	0.297	0.297	-0.001	0.00
Canada	28.338	30.021	-1.683	-5.61
	Industrial Milk Quantity (million Hectoliter)			
British Columbia	1.802	1.802	0.000	0.00
Alberta	3.009	3.393	-0.384	-11.31
Saskatchewan	1.170	1.170	0.000	0.00
Manitoba	1.778	1.778	0.000	0.00
Ontario	14.157	14.157	0.000	0.00
Quebec	21.881	22.581	-0.700	-3.10
New Brunswick	0.468	0.468	0.000	0.00
P.E.I.	0.819	0.819	0.000	0.00
Nova Scotia	0.632	0.632	0.000	0.00
Newfoundland[a]	0.001	0.000	0.001	0.00
Canada	45.718	46.800	-1.082	-2.31

Unit: 1,000,000,000 Hectoliter
Note: a: The actual output or quota of industrial milk is not available.

Table 21. Calibration to Dairy Cow Numbers, 1995

Province	Observed Data	Baseline Simulation	Difference	Percentage Difference
	Dairy Cows (1000 Head)			
British Columbia	71.85	78.00	-6.15	-7.88
Alberta	94.20	98.00	-3.80	-3.88
Saskatchewan	42.27	44.00	-1.73	-3.92
Manitoba	52.85	56.00	-3.15	-5.62
Ontario	379.55	421.00	-41.46	-9.85
Quebec	440.19	507.00	-66.81	-13.18
New Brunswick	18.60	22.30	-3.71	-16.61
P.E.I.	16.38	18.30	-1.92	-10.47
Nova Scotia	25.17	26.90	-1.73	-6.44
Newfoundland	4.15	4.50	-0.35	-7.87
Canada	1145.21	1276.00	-130.79	-10.25

Table 22. Model Validation: Output of Processed Dairy Products

	Baseline Solution	Calibration Data	Difference	Percentage Difference
British Columbia				
3.5% Milk	0.661	0.605	0.056	9.24
2% Milk	1.902	1.835	0.067	3.68
1% or Lower milk	0.813	0.821	-0.008	-1.03
Cream	0.236	0.207	0.029	14.07
Ice Cream	29.847	37.927	-8.080	-21.31
Cheddar Cheese	3.200	5.598	-2.399	-42.85
Other Cheese	3.912	4.582	-0.670	-14.62
Butter	5.765	5.266	0.499	9.47
Skim Powder	0.848	3.356	-2.508	-74.73
Other Dairy Products	7.976	16.289	-8.313	-51.04
Alberta				
3.5% Milk	0.520	0.476	0.044	9.19
2% Milk	1.496	1.444	0.052	3.61
1% or Lower milk	0.639	0.646	-0.007	-1.09
Cream	0.186	0.163	0.023	13.91
Ice Cream	32.615	23.984	8.631	35.99
Cheddar Cheese	2.064	1.643	0.421	25.64
Other Cheese	4.543	3.541	1.002	28.30
Butter	8.301	9.850	-1.549	-15.73
Skim Powder	6.522	4.636	1.886	40.68
Other Dairy Products	25.809	21.818	3.991	18.29
Saskatchewan				
3.5% Milk	0.166	0.152	0.014	9.21
2% Milk	0.478	0.461	0.017	3.66
1% or Lower milk	0.204	0.206	-0.002	-0.93
Cream	0.059	0.052	0.007	14.05
Ice Cream	13.325	15.226	-1.901	-12.49
Cheddar Cheese	2.103	2.959	-0.857	-28.95
Other Cheese	4.719	5.072	-0.353	-6.96
Butter	2.528	2.784	-0.256	-9.18
Skim Powder	0.963	1.774	-0.811	-45.74
Other Dairy Products	15.480	25.666	-10.187	-39.69
Manitoba				
3.5% Milk	0.205	0.188	0.017	8.93
2% Milk	0.590	0.571	0.019	3.24
1% or Lower milk	0.252	0.255	-0.003	-1.26
Cream	0.073	0.064	0.009	14.32
Ice Cream	17.742	17.990	-0.248	-1.38
Cheddar Cheese	5.905	7.059	-1.154	-16.34
Other Cheese	7.485	7.500	-0.015	-0.20
Butter	3.512	4.758	-1.246	-26.18
Skim Powder	2.137	2.623	-0.487	-18.56
Other Dairy Products	5.845	6.622	-0.777	-11.74

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
& 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Powder and Other Dairy Products)

Table 22. Model Validation: Output of Processed Dairy Products(Continued)

	Baseline Solution	Calibration Data	Difference	Percentage Difference
New Brunswick				
3.5% Milk	0.114	0.113	0.001	1.02
2% Milk	0.346	0.342	0.004	1.09
1% or Lower milk	0.147	0.153	-0.006	-3.95
Cream	0.042	0.039	0.003	7.60
Ice Cream	5.564	7.552	-1.989	-26.33
Cheddar Cheese	0.754	1.468	-0.714	-48.62
Other Cheese	2.083	2.515	-0.432	-17.19
Butter	1.485	1.381	0.104	7.55
Skim Powder	0.156	0.880	-0.724	-82.24
Other Dairy Products	4.812	12.730	-7.919	-62.20
P.E.I.				
3.5% Milk	0.026	0.026	0.000	0.36
2% Milk	0.079	0.078	0.001	1.31
1% or Lower milk	0.034	0.035	-0.001	-4.03
Cream	0.010	0.009	0.001	6.57
Ice Cream	8.798	11.609	-2.811	-24.21
Cheddar Cheese	1.187	2.256	-1.069	-47.38
Other Cheese	3.105	3.867	-0.762	-19.70
Butter	1.316	2.122	-0.806	-37.98
Skim Powder	0.530	1.352	-0.822	-60.79
Other Dairy Products	9.297	19.569	-10.271	-52.49
Nova Scotia				
3.5% Milk	0.189	0.188	0.001	0.62
2% Milk	0.573	0.569	0.004	0.69
1% or Lower milk	0.244	0.255	-0.011	-4.50
Cream	0.070	0.064	0.006	8.66
Ice Cream	6.651	8.083	-1.431	-17.71
Cheddar Cheese	0.960	1.571	-0.611	-38.91
Other Cheese	2.395	2.692	-0.297	-11.05
Butter	2.023	1.478	0.545	36.89
Skim Powder	0.183	0.942	-0.759	-80.60
Other Dairy Products	6.489	13.625	-7.136	-52.37
Newfoundland				
3.5% Milk	0.052	0.053	-0.001	-1.54
2% Milk	0.158	0.160	-0.002	-1.22
1% or Lower milk	0.067	0.072	-0.005	-6.69
Cream	0.019	0.018	0.001	6.57
Ice Cream	0.008	0.006	0.002	34.24
Cheddar Cheese	0.001	0.001	0.000	21.81
Other Cheese	0.003	0.002	0.001	32.83
Butter	0.003	0.001	0.002	137.31
Skim Powder	0.000	0.001	0.000	-29.98
Other Dairy Products	0.011	0.010	0.000	2.88

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
& 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Powder and Other Dairy Products)

Table 22. Model Validation: Output of Processed Dairy Products (continued)

	Baseline Solution	Calibration Data	Difference	Percentage Difference
Ontario				
3.5% Milk	1.703	1.696	0.007	0.39
2% Milk	5.156	5.140	0.016	0.31
1% or Lower milk	2.192	2.299	-0.107	-4.66
Cream	0.626	0.580	0.046	7.91
Ice Cream	155.902	140.799	15.103	10.73
Cheddar Cheese	30.509	31.403	-0.894	-2.85
Other Cheese	72.556	65.679	6.877	10.47
Butter	34.403	32.137	2.266	7.05
Skim Powder	19.090	21.676	-2.586	-11.93
Other Dairy Products	49.213	48.231	0.982	2.04
Quebec				
3.5% Milk	1.177	1.174	0.003	0.29
2% Milk	3.566	3.558	0.008	0.22
1% or Lower milk	1.516	1.591	-0.075	-4.73
Cream	0.433	0.402	0.031	7.67
Ice Cream	98.991	75.464	23.527	31.18
Cheddar Cheese	73.290	62.910	10.380	16.50
Other Cheese	126.656	101.131	25.525	25.24
Butter	37.894	36.990	0.904	2.44
Skim Powder	40.568	33.833	6.735	19.91
Other Dairy Products	54.008	48.225	5.783	11.99

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
& 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Powder and Other Dairy Products)

Chapter 7 Dairy Policy Analysis

In the previous chapter the PMP version of CRAM was solved to obtain a baseline solution for the 1995 dairy year. In this chapter, alternative policy scenarios are identified that relate to possible policy changes of reducing or removing inter-provincial trade barriers in the Canadian dairy industry. These possible policy changes are incorporated in the current model by modifying relevant constraints and activities. In order to determine the effects of these policy changes, the results under each scenario are compared to the baseline solution.

7.1 Policy Scenarios

7.1.1 Partial National Pooling of Industrial Quotas

Current dairy policy in Canada does not provide for inter-provincial movement of milk marketing quotas.[38] In the future, these restrictions might be removed and national pooling of milk marketing quotas might be established. It is more likely that the trade barriers for the industrial milk quota will be removed, for two reasons. First, under current supply management, industrial dairy products are allowed to move between the provinces, while fluid products are not. Second, industrial milk quota is regulated by the CDC, while fluid milk quota is regulated by provincial milk boards. Therefore, it is reasonable to consider the national pooling of the industrial milk quota as more likely scenario to be considered by policy makers.

[38] From August 1997 to February 1999, a limited inter-provincial quota exchange was established between Ontario, Quebec, and Nova Scotia, which was in place for a short period of time.

Some provinces may be concerned that they will lose a significant amount of marketing quota after the national pooling of quotas; therefore, it is interesting to examine the effect of pooling when industrial milk quotas are allowed to trade "partially". For example, no province would be allowed to lose more than 10%, 20%, 30%, 50%, 80%, etc. of its MSQ.

To incorporate this scenario in CRAM, a national pooled quota parameter ($Q^p{}_m$) is defined. $Q^p{}_m$ is calculated as the percentage of national MSQ that is pooled and available for reallocation among provinces. The percentage used to calculate $Q^p{}_m$ is varied to obtain "partial" pooling scenarios. As well, a new variable, $Q^p{}_{m,i}$, is defined as the allocation of pooled quota to province i; that is, the amount of nationally pooled MSQ that is endogenously allocated to a particular province.

The MSQ quota constraints in CRAM are adjusted accordingly, with a new constraint being added as well:

(7.1-a) $$S_{m,i} \leq Q^{np}{}_{m,i} + Q^p{}_{m,i} \quad \forall_i$$

(7.1-b) $$\Sigma_i\, Q^p{}_{i,m} = Q^p{}_m$$

Constraint (7.1-a) states that industrial milk production in province i ($S_{m,i}$) cannot exceed that portion of provincial MSQ that is not pooled ($Q^{np}{}_{m,i}$) plus the provincial allocation of the nationally pooled quota ($Q^p{}_{m,i}$). Constraint (7.1-b) states that the sum of all provincial MSQ allocations from the national pool will equal the MSQ available in the pool. This scenario should provide insights into comparative advantages in milk production, based on productive efficiencies, and the possibility of regional shifts in milk production patterns.

7.1.2 Regional Pooling of Fluid and Industrial Milk and Quotas

The regional milk pooling arrangements for dairy revenue (as discussed in section 2.2.5) has created the opportunity to implement a regional quota-exchange market. The Eastern and Western Pools have discussed rules for an inter-provincial quota exchange, agreeing in principle to a daily quota system. With a regional quota, the comparative advantages of each region in milk production may be better reflected. It is therefore interesting to know how the regional pooling of quotas might impact dairy farmers, processors, and consumers in each province.

In order to allow for inter-provincial movement of quotas within each region, the provincial quota constraint (i.e., condition *4.4-1g)* must be relaxed. Specifically, the original provincial quota constraints are removed and replaced with the two regional quota constraints, one for the Eastern Pool and one for the Western Pool. The constraints are structured as follows:

(7.1-c) $$\sum_w Q_{m,w} \geq \sum_w S_{m,w,} \ \forall m$$

(7.1-d) $$\sum_e Q_{m,e} \geq \sum_e S_{m,e,} \ \forall m$$

where $S_{m,w}$ is the supply of raw milk commodity m (either industrial or fluid milk) in province w of the Western Pool, $S_{m,e}$ is the supply of raw milk commodity m in province e of the Eastern Pool, $Q_{m,w}$ is the original quota allocation for raw milk commodity m in province w of the Western Pool and $Q_{m,e}$ is the original quota allocation for raw milk commodity m in province e of the Eastern Pool.

There will be limited incentive for inter-provincial movement of fluid milk quota if raw milk and fluid milk products cannot be transferred between provinces as well. Prior to the current study, inter-provincial movement of dairy products in CRAM was limited to "industrial" processed dairy products (e.g., cheese, butter). As a result, CRAM needs to be adjusted in order to allow for inter-provincial movement of raw milk and fluid milk products within each region.[39] This is done in three parts.

First, the transportation activity $X_{m,i,j}$, for movement of raw milk commodity m between province i and province j is introduced, and the transportation activity $X_{n,i,j}$ for movement of final dairy product n between province i and province j is expanded to include fluid dairy products.

Second, transportation costs for fluid milk and raw milk have to be incorporated. This process is accomplished by establishing the representative unit cost using the transport cost function (5.6-3) for fluid milk and equation (5.6-4) for raw milk. Since fluid milk products require the same type of refrigerated transportation as other industrial dairy products, it is assumed that the unit cost of transporting these products is also the same. These costs are included (i.e., subtracted) in the objective function.

Finally, the dairy balance constraints for each province must be adjusted to allow for inter-provincial movement of raw milk and fluid milk products. For fluid milk products (e.g., 20% milk), consumption plus "exports" to other provinces in the region are constrained to be no great than provincial production plus "imports" from

[39] However, only the movement of final fluid milk is incorporated in the model. In modeling this scenario, it became evident that the cost of raw milk shipment (according to equations 5.6-4) was too high to allow any

other provinces. For raw milk, provincial balance constraints for milk components (i.e., BF and SNF) are adjusted so that components used in provincial processing plus component, exported to other provinces are no greater than components supplied by provincial milk production plus components imported from other provinces.

The quota in each region will sum up ($\Sigma_r Q_{m,r}$) to a regional quota, which will be used as the restriction for regional quota constraint equations. The total quota allocation remains unchanged from the baseline model, but it may be reallocated among provinces with in each region.

7.1.3 Pooling of Special Milk Classes

As of August 1, 1995, the provinces agreed to share a common classification of milk. Specifically, milk is not placed into one of five classes. The first four classes are for milk used to process domestic products and the pricing of milk in these classes reflects domestic requirements at the going prices. Milk used in products for export as well as milk produced over-quota falls into Class 5, which has been priced according to the milk export price.

To incorporate this scenario in the empirical model, the over quota levy was removed from the original system, and all Class 5 milk received an export price. The milk export price is taken from the 1995 U.S. government supported price (i.e., \$31.12 CND per hectoliter) for milk used for processed products (Dairy Information Center web site - http://www.dairyinfo.agr.ca/ Jan, 1998). As such, this price

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physical movement of raw milk. In reality, a small amount of raw milk can be shipped across the provinces when the milk producers are close to a border.

represents a price for exports to the U.S., rather than true "world" price. The current over quota levy (i.e., $31.49/hectoliter) is replaced by the newly calculated special milk levy, which depends on the world milk price. This special milk levy is defined as the difference between domestic prices (CDC support price for industrial milk – source: Statistics Canada 1996b) and the export milk price. In CRAM it is set equal to $22.11/hectoliter.

7.1.4 Total Removal of Marketing Quotas

In the future, all inter-provincial restrictions on dairy product movement and quotas might be eliminated. In the model, this is modeled by removing the quota constraint (*4.4-1g*). All dairy products are allowed to move among the provinces in supply and demand constraints (*4.4-1b* and *4.4-1c)*. All federal subsidies to industrial milk are also removed from this model. This scenario provides an opportunity to examine the long-term adjustments that might occur from the elimination of domestic marketing quota policies, while maintaining current controls on imports.[40]

7.2 Simulation Results of Policy Scenarios

The Canadian regional agricultural model is simulated using the Non Linear Programming (NLP) procedure in the General Algebraic Modeling System (GAMS version 2.25). After establishing an initial "baseline" solution for the model (presented in previous chapter), the defined dairy policy scenarios are then examined. Solutions to each model contain the following information:

[40] Modeled in this way, the scenario does not represent complete removal of supply management.

- welfare measurements
- equilibrium outputs of milk productions
- dairy cow numbers used for milk production
- equilibrium outputs of dairy products
- equilibrium prices for dairy products
- demand quantities for dairy products
- shadow values for milk components

7.2.1 Partial National Pooling of Industrial Quotas

In this scenario simulation, the national partial pooling rates can range from 1% to 99%. However, only the results from allowing 50% of movable industrial milk quota to be traded are discussed.[41] These are presented in Table 23 to Table 28.

7.2.1.1 Welfare Implications

The results of welfare measurements (Table 28) show that the total welfare gains (including the producer surplus for the entire agricultural sector and the consumer surplus for all agricultural products) from the pooling of industrial quotas is $40 million relative to the baseline. The welfare gain comes mainly from the increase in consumer surplus in each province. With a decrease in the price of processed products and an increase in demand for processed dairy products at the national level, consumer surplus increases in each province after the partial pooling of industrial quotas. On the

[41] The results for the other partial pooling scenarios follow the same pattern as the result, discussed here. What differs are the quantitative changes.

producer side, dairy farmers and dairy processors are expected to gain in most of the provinces except Alberta, Ontario and Quebec. Although the producer surplus for dairy farmers and dairy processors decreases 3.6% and 4.8% in Alberta, and 1.5% and 1.4% in Ontario, respectively, the provincial net welfare changes (i.e., the sum of the welfare change of consumer, dairy farmer and processor) are still positive (e.g., increasing 0.1% for both provinces). Therefore, the net welfare in most of the provinces increases after this policy change. Quebec is the only province whose net welfare change is negative (-0.45%). The reasons for the patterns in welfare changes, relative to the base scenario, are discussed in the following subsections

7.2.1.2 Impact on Dairy Production and Processing Sectors

Since the national milk marketing quota is not changed, the total input of industrial milk is unchanged (approximately) at the national level. However, the provincial level production of industrial milk and industrial dairy products are impacted under this policy scenario. The dairy farmers and dairy processors in some provinces "gain" in term of welfare, while others lose.

In western Canada, British Columbia, Saskatchewan, and Manitoba increase dairy cows by 26%, 8%, and 7%, respectively relative to the baseline, and increase industrial milk production by 79%, 38% and 28% respectively. Alberta is the only province in the West that reduce 4% of its dairy cows and lost 13.6% of its industrial milk production from this policy change. The losses for industrial dairy products range from 4% for Other Cheese to 16% for Other Dairy Products.

In the East, Ontario's dairy cow numbers are reduced by 1.5% and Quebec's by 6.3% (Table 26); industrial milk production is reduced by 1.5% and 8.2% respectively (Table 26); and industrial dairy products are reduced by an average of 2% and 8% respectively (Table 26). These shortfalls in the production of industrial milk and industrial dairy products in Quebec and Ontario are captured by the other provinces in the East. New Brunswick, P.E.I., and Nova Scotia increase their dairy cow numbers by 31%, 39%, and 18%; and increase their industrial milk production by 87%, 57% and 49% respectively (Table 26).

Another interesting result is that, after the pooling of industrial milk quotas, the total movements of industrial dairy products among the provinces tend to decrease.[42] In particular, there is less export of dairy products from Quebec, Ontario and Alberta than before the pooling of quotas. This is consistent with the pattern of change in industrial milk production in those provinces.

Ontario has the highest cost for milk production. Thus, it is not surprising that this province loses industrial milk quota with a national pooling of quota. An interesting observation is that, although Quebec is a low-cost province for dairy processing, it loses industrial milk production. For example, before the pooling of industrial quotas Quebec shipped 2.86 million kilograms of ice cream and 0.71 million kilograms of butter to New Brunswick in the baseline scenario. The marginal cost in Quebec was \$0.029/kilogram less than in New Brunswick for ice-cream and \$0.055/kilogram less for butter. After pooling of industrial quotas, Quebec ships no

[42] It is difficult to report this result in detail, since there are too many variables (more than 1000 variables: ten provinces with ten dairy products in each province). However, this result may be inferred from changes in provincial dairy processing output reported in Table 23.

ice cream and only 0.072 million kilograms of butter to New Brunswick. Since the transportation cost to ship one unit of dairy product is $0.054/kilogram between these two provinces, the difference in marginal costs between Quebec and New Brunswick is $0.029/kilogram for ice cream and $0.055/kilogram for butter. Therefore it is not optimal to import ice-cream from Quebec if New Brunswick can obtain extra industrial quotas through the pooling. However, New Brunswick can still save a $0.01/kilogram by importing butter from Quebec after the partial pooling of industrial milk quotas.

When considering transportation costs, there is an obvious explanation why Quebec loses more industrial milk quota and industrial dairy products than Ontario who has higher marginal costs of milk production and processing. Looking at the geographic location of Quebec and Ontario, Quebec is closer to the Maritime provinces than Ontario. Therefore, it costs less for Quebec to ship its dairy products to the Maritime provinces than Ontario. Before the scenario, there are more dairy products shipped out of Quebec than from Ontario. For example, Ontario does not export ice cream and butter to New Brunswick, but Quebec does. After the pooling, considering relatively high transportation costs, it is cheaper for many Maritime provinces to obtain more quota to produce more processed dairy products than to import from other provinces such as Quebec. Since Quebec shipped more dairy products to the Maritime provinces than Ontario in the baseline scenario, Quebec loses more marketing milk quota.

The results also indicate that the marginal costs of milk production and milk processing are not the only forces driving inter-provincial reallocation of milk quotas and movement of dairy processed products. The reason is that the transfer of quotas costs nothing but a transportation cost is associated with the transfer of dairy products. This result highlights the importance of transportation costs in dairy modeling.[43] Therefore, under the pooling, other provinces now can produce some dairy products more cheaply than they can be imported from Quebec.

The percentage changes in dairy cow numbers are lower than the percentage changes in industrial milk because fluid milk production is acting as a buffer in the model. Although this policy has an impact on the production of industrial milk in most provinces, the output of fluid milk does not change significantly across the provinces. Moreover, the changes in fluid milk production in each province tend to compensate the change of industrial milk production, since some fluid milk components (i.e., BF and SNF) can be used for producing industrial dairy products. Therefore, when provinces gain industrial milk quota (e.g. Manitoba, New Brunswick and PEI), fluid milk production will actually decrease in these provinces. However, fluid dairy product processing (e.g., table milk) which uses fluid milk as an input are not decreased in these provinces. This is an indication that fluid milk components were being used in industrial milk processing in these provinces, for this baseline solution.

The shadow values for milk components (i.e., BF and SNF) are presented in Table 27. The shadow values for butterfat from industrial milk decrease for most provinces in which the total milk production increases. The shadow values for the butterfat from industrial milk increase in those provinces in which the total milk

[43] The sensitivity of solutions to transportation costs is explored later in this chapter.

production decreases. The more scarce the limited resource (e.g., the raw milk), the higher the value of the shadow value for this resource. The largest decrease is –39% in New Brunswick, where the value is $3.546 per kilograms of butterfat in the baseline solution and $2.149 per kilogram of butterfat after the pooling of the industrial milk quotas. The value in Ontario does not change significantly since milk production in Ontario does not change much under the partial pooling scenario. For those provinces with less raw milk available, the shadow values of raw milk or the component of raw milk will increase. Since Quebec and Alberta lose industrial milk quota, the shadow values for butterfat in these provinces increased by 3.48% and 3.13% respectively.

The shadow values for SNF of industrial milk display the same pattern as those for butterfat. The largest drop in the shadow value of SNF occurs in British Columbia, decreasing from $3.284 per kilogram to $1.441 per kilogram (or –56%). Since Quebec and Alberta lose industrial milk quota, the shadow values for SNF increase by 27% and 62% respectively. The changes in shadow values for SNF of fluid milk are almost identical to the changes in shadow values of SNF for industrial milk. This is another indication of the link between fluid and industrial milk processing, in terms of the transfer of milk components.

7.2.1.3 Impacts on Dairy Consumption Sector

In general, consumers gain from the partial quota pooling scenario, because of a decrease in dairy product prices and a corresponding increase in dairy product consumption. After the pooling, prices for most processed dairy products decrease. Reallocation of quotas reduces the total transportation cost of transferred dairy products among provinces and therefore reduces the national price level. Because of the price decrease in most dairy products, the domestic demands for most processed product increase slightly (up to 4.8%). In this scenario, all consumers of dairy products gain from this policy change.

7.2.2 Regional Pooling of Fluid and Industrial Quota and Inter-provincial Transfer of Fluid Milk Products

As noted in section 7.1.2, in this scenario, the provincial industrial and fluid milk quota constraints are replaced with regional (i.e., West and East) quota constraints. Doing so will allow for inter-provincial movement of quotas within each region. As well, inter-provincial movement of fluid milk products is incorporated by expending the set of dairy product transportation activities.

7.2.2.1 Welfare Implications

The welfare measurements (Table 28) show that, in general, national welfare increases by approximately $60 million (or 0.21% from baseline) for this scenario. Due to the decreased price for processed products and a corresponding increase in demand at the national level, consumer surplus increases in each province. On the producer side, dairy farmers and processors gain in most of the provinces except Alberta and Quebec. Alberta is the only province whose net welfare change is negative (-0.34%). Although the producer surplus for dairy farmers and dairy processors decreases 1.3% and 2.1% in Quebec, respectively, the provincial net welfare measurement is still positive (i.e., increases by 0.6%). Therefore, the net welfare in most of the provinces increases after this policy change. Reasons for the patterns in welfare change, relative to the base scenario, are discussed in the following subsections.

7.2.2.2 Impact on Dairy Production and Processing Sectors

The dairy farmers and dairy processors in most provinces gain from this scenario. In the western provinces, for example, British Columbia, Saskatchewan, and Manitoba increase their dairy cow numbers by 14%, 9% and 2%, respectively. Alberta is the only province in the West that loses cows (-8%) and industrial milk production (-26%) from this policy scenario. The loss in Alberta's industrial dairy processing ranges from 13% for butter to 33% for other dairy products. Although British Columbia loses 8.4% (or 0.31 million hectoliter) of fluid milk quota. While losing industrial quota, Alberta gains 8.7% (or 0.24 million hectoliters) of fluid milk quota.

The resulting decrease in production of fluid dairy products in British Columbia is captured by increased production in Alberta and Saskatchewan. Alberta produces 0.23 million hectoliters more fluid milk including 0.02 million hectoliters of 3.5%BF milk, 0.14 million hectoliters of 2% BF milk and 0.07 million hectoliters of low fat milk than were produced in the baseline scenario. Most of these products are shipped to British Columbia. Saskatchewan has an increase of 0.05 million hectoliters in fluid milk production, which includes 0.02 million hectoliters of 3.5%BF milk, 0.01 of 2% BF milk and 0.02 million hectoliters of low fat milk.

In this baseline solution, Alberta shipped industrial dairy products to British Columbia and Saskatchewan. However, under this scenario, Alberta reduces its industrial dairy products for export. This is offset by increased production in British

Columbia and Saskatchewan. Therefore, inter-provincial movement of industrial dairy products decreases in the western provinces.

Although British Columbia has the highest marginal processing cost for both fluid and industrial dairy products, British Columbia still gains industrial milk marketing quota. British Columbia's marginal processing costs for fluid milk products are approximately 25% higher than for Alberta. Meanwhile, Saskatchewan has an even lower marginal cost for fluid milk products and cream. Therefore, it is more economical for British Columbia to pay some transportation costs to import fluid dairy products from other western provinces than to produce them in British Columbia. Since most of British Columbia's fluid dairy products are imported from Alberta, Alberta obtains more fluid quota. For industrial dairy products, the difference in the marginal processing cost of production between British Columbia and other western provinces is approximately 3%. Therefore, it is optimal for British Columbia to obtain industrial milk quota and increase industrial dairy processing level instead of importing from Alberta, which has a lower marginal cost.

In the East, most provinces except Quebec increase their total milk production and number of dairy cows. New Brunswick, P.E.I. and Nova Scotia increase their dairy cow number by 32%, 44% and 18%, respectively. Quebec is the only province to lose cow (-2.3%), reduce industrial milk production (-6.4%), and reduce industrial dairy processing (from 3% for butter to -12% for other dairy products).

These reductions in production of industrial milk and industrial dairy products are offset by the increase in the other provinces in eastern Canada. The production of industrial dairy products is increased in most of the Maritime provinces. The production in Ontario is virtually unchanged from the baseline scenario. Compared with the partial national pooling of quotas, Ontario shows a different pattern of change under this regional pooling scenario. This difference implies that Ontario exports its industrial dairy products mainly to its western neighbors. In this scenario, the Western provinces cannot obtain quota from Ontario to produce their own industrial dairy products; therefore, Ontario can maintain baseline production levels and still ship its industrial products to the West.

Although Quebec loses industrial quota, it obtains 11% or 0.74 million hectoliters of fluid milk quota. The industrial dairy production can and has to obtain some milk components (i.e., BF or SNF) from the fluid milk quota in order to have enough BF and SNF, since the BF and SNF from the industrial milk quota are less than the actual demand for industrial dairy products. For example, in the baseline solution, the total demand for BF from industrial dairy products is 210 million kilogram, while the total MSQ only provides 180 million kilograms of butterfat. On the other hand, the total demand for BF from fluid milk is 75 million kilograms; however, the total BF supplied from the fluid quota is over 115 million kilogram. Therefore, when Quebec loses 1.39 million hectoliters of industrial quota, the processors tend to obtain more components from the fluid milk sector and try to maintain their capability to produce industrial dairy products.

The quota constraints for both industrial milk and fluid milk are building in the western pool. The shadow value for fluid milk quota is $8.287 per hectoliter and $11.7 per hectoliter for industrial milk in the western provinces.[44] In the eastern pool,

[44] It should be noted that the units for the shadow values are $ of net social payoff.

the industrial milk quota constraint is binding; the shadow value for the industrial milk quota is $2.62 per hectoliter. The fluid milk quota constraint is not binding in this scenario. The high shadow value in the western provinces and the non-binding quota constraint in the eastern pool may suggest that the western provinces may bid for more milk quota from the East under a national pooling of milk quotas.

In the western provinces, the shadow values for butterfat for industrial milk decrease in most of the provinces in which the total milk production increases. Since more quota or raw milk is available, the implicit values of these milk components will not be as high as before. The largest decrease is 21% for British Columbia, in which the value is $3.493 per kilogram of butterfat in the baseline solution and $2.761 per kilogram of butterfat after regional pooling. In the West, Alberta loses industrial milk quota and its shadow value for butterfat increases by 6.72%. As for the previous scenario, the change in the butterfat shadow values for fluid milk is almost the same as that for industrial milk.

The SNF shadow values for industrial milk have the same pattern as those for butterfat; the values decrease in all the provinces in which the total milk production increases. The largest shadow value decrease occurs for British Columbia, in which the SNF shadow value for industrial milk decreases from $3.284 per kilogram to $2.015 per kilogram (or –39%). An increase for the SNF shadow values for fluid milk occurs in Alberta (i.e., from $0.396 to $1.466 per kilogram of SNF), despite the fact that Alberta gains fluid milk quota and production, because total milk production (and thus total supply of SNF) decreases in the province.

In the eastern provinces, the SNF shadow values decrease in most provinces in which total milk production increases. The largest decrease is –44% for New Brunswick, in which the value is $3.479 per kilogram of SNF in the baseline solution and $1.935 per kilogram after regional pooling. The shadow value of BF in industrial milk in Quebec increases by 33% since it loses milk quota. The shadow value of BF in Ontario does not significantly change since the industrial milk production does not change significantly in this province. Since the fluid milk production decreases in Ontario, the shadow value of fluid milk SNF increases by 7.8%. The shadow value of fluid milk SNF in Quebec decreases slightly when it gains the fluid milk quota.

In the eastern provinces, the butterfat shadow values decrease significantly for most of the provinces in which the total milk production increases. The largest decrease is -31% for New Brunswick, in which the value is $3.546 per kilogram of butterfat in the baseline solution and $2.434 per kilogram of butterfat after regional pooling. However, the shadow value of BF in Quebec does not significantly change although Quebec loses of its milk quota. The implication is that after regional pooling of milk quota, the eastern provinces still have sufficient butterfat for the dairy-processing sector and the BF is distributed to each province "more evenly". Therefore, the general shadow value decreases for most of the eastern provinces after the regional pooling of milk quotas. The change in the butterfat shadow values for fluid milk is almost the same as that of the butterfat shadow values for industrial milk.

7.2.2.3 Impacts on Dairy Consumption Sector

In general, consumers gain from this scenario because of the decrease in processed dairy product price and the corresponding increase in processed dairy product demand. Since reallocation of quotas reduces the total transportation cost involved in transferring dairy products among provinces, prices are reduced at the national level.

7.2.3 Pooling of Special Milk Classes

In this scenario, milk used in processed products for export, as well as milk produced over-quota fall into Class 5, which is priced according to the an export price.[45] This change may affect both the milk producers who sell raw milk and the dairy-processors who use raw milk as an input in dairy processing.

In general, no significant change occurs for the Canadian dairy industry under this scenario. Neither milk production nor export of dairy products changes significantly (e.g., less than 1%) at the current export price level ($31CND). This result is consistent with the sensitivity analysis, which shows that only when the over-quota levy decreases to a lower level (e.g. 80% of the 1995 level, approximately $17.68/hectoliter), will volumes in this special milk class begin to increase significantly (i.e., above 5% of total milk production) in some provinces. Milk production for this special milk class occurs mostly in the smaller provinces (e.g., British Columbia, Saskatchewan, New Brunswick, PEI, and Nova Scotia). After some significant production in this special milk class, exports of processed dairy products from Canada will increase slightly. The two products that increase the most in

[45] As noted in Chapter 5, this export price reflects U.S. prices rather than a world price.

production are skim milk powder and ice cream, which have a high content of SNF and a low content of butterfat. This increase implies that this special milk class will provide extra SNF to the world market and supply part of its butterfat to the domestic market.

7.2.4 Free Market Scenario Without Quotas and Government Subsidies

In this scenario, all inter-provincial restrictions on quotas and dairy product movement are eliminated for both fluid and industrial dairy products. This scenario then provides an opportunity to examine the long-term adjustments that might occur from the elimination of domestic supply control policies, while maintaining current controls on imports.

7.2.4.1 Welfare Implications

In comparison with other policy scenarios (as in Table 28), the national welfare increases by $278 million (or 1.4% from baseline) under this scenario. Consumer surplus and producer surplus for both dairy farming and processing sectors increase in most provinces. Alberta and Quebec have relatively small welfare decreases on the production side.

For the dairy farmers, the producer surplus increases by 20% to 40% in most provinces. Quebec and Alberta are the only provinces in which producer surplus for dairy farmers decreases slightly (1.22% and 3.23%, respectively) because of decreased milk production. Producer surplus for dairy processors increases in most provinces (e.g., from 1.29% increase in Ontario to 40% in P.E.I.). Again, Alberta and Quebec are the only exceptions. The producer surplus for dairy processors in Alberta and

Quebec decreases by 0.11% and 2.42%, respectively. However, increases in the consumer surplus for these provinces offset producer and processor losses. As a result, the net welfare increases in all provinces.

In general, consumers gain from this scenario. The consumer surplus increases across all the provinces and increases approximately 0.7% at the national level. This increase is mainly because of a slight decrease in the price of most fluid and processed products resulting in a slight increase in demand for both fluid and processed products.

7.2.4.2 Impact on Dairy Production and Processing Sectors

After removing the quota constraints and inter-provincial trade restriction, no significant increase occurs in total milk production. The total national milk production increases 4.14% or 3.09 million hectoliters. National dairy cow numbers increase by 4.08% (or 46,775 head). This increase implies that the current national milk quota is slightly lower than is warranted by actual domestic demand for dairy products. British Columbia, Saskatchewan, Manitoba, Ontario, New Brunswick, P.E.I. and Nova Scotia increase their dairy cow numbers by 24%, 23%, 15%, 1.6%, 31%, 43%, and 17%, respectively. Alberta and Quebec are slightly reduced (i.e., less than 2.6%). Total movement of industrial dairy products among provinces tends to decrease. There is less export of dairy products from Quebec and Alberta than for the baseline solution.

Since there is no significant change of dairy cow numbers in major milk production provinces such as Ontario, Quebec and Alberta, this scenario does not have a significant impact on other related agricultural sectors such as crop production and beef production. Hay production increases in many provinces with increased milk production, such as British Columbia, Saskatchewan, Ontario, New Brunswick, P.E.I. and Nova Scotia (by 36%, 42%, 1.6%, 54%, 22% and 25% respectively). The production of other crop remains at the same level as the baseline. This result may suggest that the resource constraint of crop production is not yet binding in the model. The beef industry is also not significantly impacted by this scenario. Beef production does not change after a slight increase in the beef supply as a by-product of removing the dairy quota.

Most of the increased milk production resulting from this scenario goes to industrial milk production, which increases by 6.7% or 3.1 million hectoliters. British Columbia, Saskatchewan, Manitoba, Ontario, New Brunswick, P.E.I. and Nova Scotia increase their industrial milk production by 87%, 63%, 30%, 4.5%, 98%, 64%, and 60%, respectively. Meanwhile Alberta and Quebec reduce their industrial milk production by 9.8% and 6.7%, respectively. The decreases in industrial milk production in these two provinces are because of the transportation cost of transferring the processed dairy products to other provinces, as explained in previous scenarios. The increased production of industrial milk and industrial dairy products in other provinces is because of the increase in domestic demand and/or the reduction in imports from Quebec or Alberta.

The productions of fluid milk and fluid dairy products are consistent with the earlier scenario regarding the regional pooling of milk quotas. Most provinces except Quebec and Alberta reduce their fluid milk production. Quebec and Alberta increase fluid milk production by 10.8% and 10.1%, respectively. These two provinces increase fluid milk production because, as explained before, there is increased demand for milk components (e.g., BF) from fluid milk. Also, as explained before, British Columbia and the Maritime provinces reduce their production of both fluid milk and fluid dairy products because of higher marginal costs of fluid dairy processing.

The shadow values for milk components (i.e., BF and SNF) are presented in Table 27. After removal of quota restrictions, the shadow values for butterfat of both industrial milk and fluid milk decrease for all the provinces, ranging from 5.7% in Alberta to 37% in British Columbia. The shadow values for SNF decrease for most provinces in which the total milk production increases, but the shadow values increase in Alberta and Quebec. However, even after the increase, the total national level of the shadow value of SNF is still relatively low in these provinces (i.e., $0.89 and $1.336 per kilogram of SNF for Alberta and Quebec respectively). This increase occurs because the initial value in the baseline is very low in these two provinces. In general, after removing quota restrictions, the national level of the shadow values of milk components are expected to decrease significantly. Therefore, the input costs of the dairy-processing sector and the prices of dairy products are expected to decrease after removing quota restrictions from the Canadian dairy industry.

7.2.4.3 Impacts on Dairy Consumption Sector

Because the prices of processed products decrease and the demands for processed dairy products increases, consumers gain from this scenario, as noted earlier. After removing industrial and fluid quotas, prices for most processed dairy products are decrease. Prices for fluid dairy products decrease by approximately 34% (i.e., weighted average) at the national level (i.e., 30% decrease for standard table milk, 34.5% for 2% milk and 36.8% for 1% and skim milk). The price of industrial dairy products decreases approximately 5% (i.e., weighted average). Since fluid milk production was limited at a provincial level and no transfer of final fluid products was allowed for the baseline scenario, the differences in the marginal processing cost for fluid products among high efficiency provinces are higher than those for industrial products. When the inter-provincial trade barriers are removed, some low efficiency provinces in which the fluid milk price was high are expected to import fluid milk from provinces with a lower price. For this reason, the prices of fluid dairy products drop to a greater degree than the prices of industrial products after removal of inter-provincial trade barriers.

7.3 Discussion of Empirical Results

From the policy scenarios discussed in the previous sections, some general results may be identified. In particular, consumers tend to gain from inter-provincial trade liberalization. As well, producers and processors in most provinces also gain, in terms of welfare. The exceptions to this pattern are in Quebec and Alberta where there tend to be "losses" for producers and processors, defined in terms of milk production, dairy processing levels and/or welfare measures. The previous sections do provide some discussion and explanation with respect to these results for each scenario. However, in this section, these results are "tied together" in terms of general patterns.

The intuition behind the pattern in consumer gains is relatively straightforward. Each scenario involves removal of some restriction related to domestic dairy policy. It is not unexpected, therefore, that the impact on consumer welfare is positive. More "efficient" inter-provincial allocation of dairy production and processing results in lower demand prices. This, in turn, benefits consumers. As well, from a mathematical programming perspective, the scenarios tend to involve relaxation or removal of constraints. This will result in either no change or improvement in the objective function value which, in this case, represents total welfare.

The intuition behind the patterns in dairy production and processing is not quite so transparent. Quebec loses milk production and dairy processing to the Maritime provinces, despite having comparable (and even lower in some cases) marginal costs for dairy products. This result is "counter" to the empirical evidence from the limited quota exchange that was in place for a time, between Nova Scotia, Quebec and Ontario. The result of that quota exchange was a net transfer of quota from Ontario and Nova Scotia to Quebec producers.

Also, the model results for the policy scenarios suggest that Alberta would lose milk production and dairy processing to other western provinces. This result seems somewhat counterintuitive given that Alberta has the second lowest marginal cost (in terms of $ per hectoliter) for milk production in the region (only British Columbia has a lower marginal cost) and also has lower marginal costs for dairy processing than other western provinces.

A partial explanation for the Quebec results may relate to the historical allocation of industrial milk quotas. As noted in Chapter 2, there has been little change in provincial allocations of MSQ over time in response to any changes in population distributions and/or dairy demand patterns. In particular, Quebec has maintained a large proportion of national MSQ relative to its population and, as a result, has been a net exporter of processed dairy products to other provinces. Given the relative differences in marginal costs of production and processing in eastern Canada, versus the costs of transporting dairy products between provinces in the model, it may be optimal to shift production and processing closer to the source of demand in the model.

In western Canada, Alberta has low marginal costs for milk production, but the marginal cost for British Columbia (again, defined in terms of $ per hectoliter) is even lower. As a result, given the population in British Columbia which in turn affects dairy product demand, it is optimal to shift production and processing from Alberta to British Columbia.[46] Also, the geographic distances involved in shipping dairy products between provinces in western Canada are significant. As a result, given the relative differences in marginal costs of production and processing in western Canada, versus the costs of transporting dairy products between provinces in the model, it may be optimal to shift production and processing closer to the source of demand in the model.

The exception to this result in western Canada is with respect to fluid milk production and processing. If inter-provincial restrictions are relaxed for fluid milk in CRAM, production shifts from British Columbia to Alberta. In fact, this is consistent with limited empirical observations for the two provinces. In the model, there is a significant difference between the two provinces in marginal costs of processing for fluid milk products. As a result, it is optimal to shift production from British

[46] As noted in Chapter 2, the level of MSQ in British Columbia is low relative to its population.

Columbia to Alberta, as the benefits from less expensive processing outweigh the costs of transportation.

Another possible explanation for the model results, particularly in light of the recent quota exchange evidence, is that the results of the policy scenarios modeled in this study are "long term" in nature. In other words, there may be significant short-term adjustments that occur that deviate from the long-term equilibrium as defined by these policy scenario results. For example, it is possible that the results of the inter-provincial quota exchange noted earlier may be driven by short-term "strategic" behavior by Quebec dairy producers to acquire a larger share of the domestic dairy market. While rational, this behavior may not be consistent with the underlying assumptions of CRAM in terms of producer objectives. Producers in Quebec may also have different expectations concerning the future of the dairy industry than producers in other provinces. This possibility is also not considered within the assumptions underlying the empirical model in this study.

The pattern of results may also be in part due to study limitations. These limitations relate both to the model itself and the data used to update the model parameters. For example, CRAM ignores certain costs that would be associated with significant regional shifts in dairy production and processing. These include investment costs necessary to increase dairy production and processing capacity, and the transfer costs associated with quota. As well, it is not clear that CRAM adequately deals with economies of scale in dairy processing, which would affect any trend towards reduced concentration in the dairy processing sector.

In terms of data limitations, there is a lack of detailed data concerning dairy processing costs. This was outlined in the discussion in Chapter 5 concerning marginal cost estimation. Also, consumption patterns (i.e., per capita consumption) are assumed to be constant between provinces in this study. This assumption is necessary because demand information for dairy products is only available at a national level. It is likely that per capita consumption of dairy products differs significantly between provinces. However, without adequate data it is impossible to incorporate this into the analysis.

As noted in Chapter 3, a limited number of studies have addressed interprovincial trade considerations in the Canadian dairy sector. Ewascechko and Horbulyk (1995) present results that are somewhat consistent with those from the current study. They conclude that the reallocation of existing quota across farms and provinces has the potential to reduce the costs of industrial milk production and the cost of transporting products. Their study suggests that dairy production would increase in all western provinces (including Alberta), which differs from the results presented here. Similar to the results here, however, they suggest that milk production in Quebec would decrease after removal of quotas.

Mussell and Goddard (1996) also address inter-provincial trade liberalization. In contrast to the results presented here, they conclude that Quebec would gain MSQ if quotas were allowed to transfer between provinces. A limiting factor in their study, however, is that transportation costs are not considered, and Mussell and Goddard (1996) do not incorporate the processing sector in their analysis.

7.4 Sensitivity Analysis

This section considers the extent to which the results are sensitive to the numerical specifications of the model. Sensitivity analysis is helpful in order to understand the performance of the model. A number of essential parameters or specifications are identified for the sensitivity analysis of inter-provincial trade liberalization. These parameters include transportation cost, demand elasticity, supply elasticity for milk production, and supply elasticity for milk processing.

In the sensitivity analysis, the values of these parameters are changed one at a time. While the sensitivity analysis can be carried out for all scenarios, a significant amount of results would then need to be presented. A good understanding of the model's general performance can be achieved by performing a sensitivity analysis on any one of the policy scenarios. In this study, sensitivity analysis is performed for the fourth scenario: the total removal of domestic marketing quotas.

In the sensitivity analysis, the model will generate all of the results presented in the previous discussion for each parameter change. Many simulation results can be reported for the sensitivity analysis; however, it is not necessary to report all of them for each parameter change. Instead, it might be more clear and efficient to choose a limited number of parameters or just one parameter, which would be representative of the changes for many of the other variables in the model. A good candidate for this simplification is the number of dairy cows in each province.[47] From the change in this

[47] Other variables can be chosen to report here, such as the ten final dairy products for each province, or fluid milk and industrial milk. However, many more results need to be represented for these variables.

variable, insight can be obtained regarding the change in total milk production (i.e., exactly the same change as that in the dairy cow numbers in each province), the approximate production of processed dairy products at a provincial level, and the total demand for dairy products at a national level (same change in direction as for milk production). Therefore, dairy cow numbers are reported as an index to reflect all the changes by sensitivity analysis that is applied to against the scenario of removing milk quotas in model.

7.4.1 Sensitivity Analysis on Demand Elasticity

As the model has ten demand elasticities, testing the range of each elasticity one by one is difficult. Instead, the demand elasticities for all the products are changed simultaneously in a range of 50%, 70%, 90%,100%,110%,130%, and 150%. Then all the possible elasticities from the previous study (as shown in Table 11) are addressed in this sensitivity analysis. The results of the sensitivity analysis are presented in Table 29. The equilibrium numbers of dairy cows change positively with the changes in demand elasticities. However, the change in quantity demanded and production in each province is small. When the elasticities increase 10% from the baseline, each province increases its number of dairy cow by 0.6% to 2%. Over the simulated range of change in demand elasticities (i.e., from -50% to +50%), the national total milk production is changed only from 1,151 million hectoliters to1,223 million hectoliters (6.25% increase). Therefore, the simulation results for this policy change do not appear to be sensitive to the range of demand elasticities.

7.4.2 Sensitivity Analysis on Supply Elasticity

Previous studies suggest that the supply elasticity estimates for milk production in the North American market are in the a range of 0.23 to 8.0 (Meilke et al. 1998, p. 154). In the sensitivity analysis, the milk supply elasticity varies within this range while all the other parameters are kept unchanged. The change in quantity of production among the provinces is stable (less than 1.7% change) when the elasticities change from 0.23 to 8.0. The variation of milk supply elasticity does not change Quebec's position, where it loses milk production after removal of marketing quotas.

The overall equilibrium quantity has a negative relationship with the raw milk supply elasticities. The relationship may differ from that of normal expectations such as the sensitivity analysis of the supply elasticity for dairy processing, possibly because of the model's structure. The demand for raw milk is a derived demand, which is not built into the model directly. When the price of final dairy products falls as a result of removing quotas, the demand for dairy products will increase, thus requiring more raw milk; therefore, the price of raw milk tends to increase instead of moving in the same direction as that of final dairy products.

When the elasticities decrease from the baseline, each province increases its milk production slightly. When the supply elasticity changes to 0.8 (from 1.0), Alberta begins to increase its milk production and dairy processing after the removal of marketing quotas. When the supply elasticities decrease by 0.2, national production of milk increases by 1.7% from the original scenario. When the supply elasticity reaches the upper level (8.3), the national production of milk increases 3.7% from the baseline (or 1.7% decrease from scenario with original supply elasticity). The pattern of milk production in each province is the same when elasticity changes from 0.8 to 8.3. Therefore, different values of the milk supply elasticity of dairy products will not change the simulation results significantly.

Since no previous study of supply elasticities of dairy processing in Canada or the United States can be found, the supply elasticities will be varied in a wide range between 0.1 to 1.5. Only a -50% and +50% change of the supply elasticities of dairy processors is presented in Table 30. The quantity of dairy product production in each province is relatively stable when the supply elasticities change. The overall equilibrium quantity has a positive relationship with the supply elasticities. When the elasticities increase from the baseline, each province increases its milk production slightly. When the supply elasticity increases to 1.1, Alberta increases its milk production and dairy processing after the removal of its quota. However, over the simulated range of elasticities, the total national change in dairy cow numbers is less than 3.5%. When the supply elasticities decrease to 0.1, national production of milk and dairy products tends to be the same (i.e., only a 0.5% difference) as the baseline results.

7.4.3 Sensitivity Analysis on Transportation Cost

The unit transportation cost (UTC) is an important parameter for trade liberalization. A quadratic transportation cost functional form (Ward and Farris 1988) is used for this study. The unit transportation cost from this quadratic form is higher (i.e., roughly 40%) than the value used in the current CRAM (i.e., $32CND for the same distance). For example, it costs $55CND to ship 1000kg of butter from Alberta to British

Columbia. The UTC is changed by 50% to 200% in the sensitivity analysis. The results are reported in Table 32. Sensitivity analyses show that with a decrease in the UTC, Quebec and Alberta tend to lose less milk production. For example, when the UTC is reduced to the 50% of its initial level, Alberta begins to increase its industrial milk production (instead of losing production in the current scenario) while other provinces tend to gain less. When UTC is increased by 50%, the Quebec and Alberta tend to lose more milk production. When the transportation cost increases, each small province will tend to produce more to meet its own demand rather than import from other provinces such as Quebec and Alberta. However, the model results are still relatively stable for the change in UTC. For example, after a 50% UTC change, Quebec gains only 0.56% in milk production, and the national price of dairy products drops by only 0.1%.

7.4.4 Summary of Sensitivity Analysis

Sensitivity analyses show that the overall empirical results are stable for most of the parameters tested. This finding implies that the model has a certain degree of tolerance for possible errors in the estimation of these parameters; a change in any of these parameters will not change the overall model significantly. The results of sensitivity analysis make us more confident of the scenario results.[48]

[48] The sensitivity analysis conducted for this study focuses on aggregate changes in parameters. It does not address the sensitivity to possible error in relative values between provinces.

Table 23. Empirical Results: Provincial Output of Dairy Processed Products

	Scenario[a]								
	1	2		3		4		5	
	Quantity	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]
British Columbia									
3.5% Milk	0.66	0.68	2.29	0.63	-5.22	0.66	0.16	0.64	-3.41
2% Milk	1.90	1.92	0.78	1.76	-7.36	1.90	0.06	1.78	-6.65
Low Fat Milk[c]	0.81	0.82	0.73	0.73	-10.08	0.81	0.05	0.74	-9.07
Cream	0.24	0.24	2.26	0.23	-3.76	0.24	0.15	0.24	1.65
Ice Cream	29.85	44.46	48.97	41.55	39.22	31.00	3.88	46.19	54.74
Cheddar Cheese	3.20	6.41	100.41	5.42	69.25	3.40	6.33	6.67	108.48
Other Cheese	3.91	5.77	47.41	5.17	32.05	4.03	2.98	5.89	50.65
Butter	5.77	7.98	38.43	6.92	20.10	5.92	2.62	7.64	32.60
Milk Powder[d]	0.85	3.24	281.90	2.61	208.14	1.00	17.61	3.59	323.50
Other Dairy[e]	7.98	15.56	95.04	13.49	69.16	8.54	7.01	16.39	105.52
Alberta									
3.5% Milk	0.52	0.53	2.29	0.55	6.01	0.52	0.16	0.56	7.95
2% Milk	1.50	1.51	0.78	1.64	9.59	1.50	0.06	1.65	10.28
Low Fat Milk[c]	0.64	0.64	0.74	0.71	10.94	0.64	0.05	0.72	12.16
Cream	0.19	0.19	2.26	0.19	0.21	0.19	0.15	0.20	7.70
Ice Cream	32.62	29.69	-8.96	25.90	-20.60	32.55	-0.19	30.05	-7.86
Cheddar Cheese	2.06	1.90	-7.87	1.57	-24.02	2.06	-0.13	1.93	-6.69
Other Cheese	4.54	4.34	-4.49	3.83	-15.70	4.54	-0.05	4.38	-3.70
Butter	8.30	7.65	-7.84	7.24	-12.78	8.29	-0.13	8.11	-2.34
Milk Powder[d]	6.52	5.93	-9.08	4.59	-29.69	6.51	-0.14	5.96	-8.64
Other Dairy[e]	25.81	21.50	-16.70	17.40	-32.57	25.75	-0.22	21.58	-16.38
Saskatchewan									
3.5% Milk	0.17	0.17	2.29	0.19	12.15	0.17	0.16	0.19	11.56
2% Milk	0.48	0.48	0.78	0.49	2.85	0.48	0.06	0.48	1.06
Low Fat Milk[c]	0.20	0.21	0.73	0.22	9.50	0.20	0.05	0.22	6.09
Cream	0.06	0.06	2.26	0.07	20.71	0.06	0.15	0.08	29.84
Ice Cream	13.33	16.43	23.27	14.19	6.45	13.31	-0.11	16.82	26.24
Cheddar Cheese	2.10	2.97	41.00	2.47	17.58	2.10	0.04	3.03	43.89
Other Cheese	4.72	5.75	21.77	5.25	11.24	4.72	0.07	5.80	22.95
Butter	2.53	3.18	25.75	2.66	5.04	2.53	-0.05	3.05	20.50
Milk Powder[d]	0.96	1.56	61.63	1.26	30.99	0.96	0.13	1.66	72.10
Other Dairy[e]	15.48	20.29	31.07	16.42	6.06	15.46	-0.12	20.85	34.68
Manitoba									
3.5% Milk	0.21	0.21	2.29	0.21	1.26	0.21	0.16	0.21	3.15
2% Milk	0.59	0.59	0.78	0.59	0.44	0.59	0.06	0.61	3.15
Low Fat Milk[c]	0.25	0.25	0.73	0.25	0.45	0.25	0.05	0.27	6.88
Cream	0.07	0.08	2.26	0.08	3.56	0.07	0.15	0.09	17.71
Ice Cream	17.74	20.58	15.99	17.85	0.62	17.72	-0.13	21.00	18.35
Cheddar Cheese	5.91	7.34	24.24	6.14	4.02	5.91	-0.01	7.47	26.47
Other Cheese	7.49	8.55	14.19	7.81	4.40	7.49	0.04	8.63	15.32
Butter	3.51	4.08	16.00	3.56	1.38	3.51	-0.04	4.06	15.50
Milk Powder[d]	2.14	2.86	33.61	2.31	8.29	2.14	0.02	2.95	37.83
Other Dairy[e]	5.85	6.60	12.96	5.46	-6.55	5.84	-0.14	6.70	14.70

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
and 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. Low Fat milk includes 1% and skim milk.

d. Milk Powder is Skim Milk Powder.

e. Other Dairy is Other Dairy Products.

Table 23. Empirical Results: Provincial Output of Dairy Processed Products (Continued.)

	Scenario[a]								
	1	2		3		4		5	
	Quantity	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]
New Brunswick									
3.5% Milk	0.114	0.114	0.013	0.111	-2.584	0.114	0.000	0.111	-2.412
2% Milk	0.346	0.346	-0.012	0.304	-12.209	0.346	0.000	0.303	-12.406
Low Fat Milk[c]	0.147	0.147	-0.027	0.129	-12.263	0.147	-0.001	0.128	-13.099
Cream	0.042	0.042	0.188	0.050	18.436	0.042	0.004	0.049	17.418
Ice Cream	5.564	8.091	45.427	8.539	53.476	5.559	-0.084	8.460	52.053
Cheddar Cheese	0.754	1.428	89.319	1.499	98.750	0.755	0.133	1.492	97.758
Other Cheese	2.083	2.930	40.649	2.987	43.386	2.085	0.113	2.990	43.554
Butter	1.485	2.147	44.596	1.983	33.560	1.485	0.004	1.964	32.231
Milk Powder[d]	0.156	0.591	278.356	0.720	360.827	0.157	0.619	0.699	347.496
Other Dairy[e]	4.812	9.268	92.629	10.071	109.303	4.807	-0.099	9.992	107.657
P.E.I.									
3.5% Milk	0.026	0.026	0.013	0.024	-9.572	0.026	0.000	0.024	-9.015
2% Milk	0.079	0.079	-0.012	0.067	-15.597	0.079	0.000	0.067	-15.027
Low Fat Milk[c]	0.034	0.034	-0.027	0.030	-11.889	0.034	-0.001	0.030	-11.571
Cream	0.010	0.010	0.188	0.009	-4.082	0.010	0.004	0.010	0.004
Ice Cream	8.798	11.411	29.699	12.019	36.608	8.791	-0.082	11.897	35.224
Cheddar Cheese	1.187	1.966	65.600	2.054	73.002	1.189	0.131	2.054	73.029
Other Cheese	3.105	4.072	31.151	4.024	29.590	3.109	0.116	4.173	34.383
Butter	1.316	2.006	52.375	2.087	58.498	1.317	0.010	2.055	56.089
Milk Powder[d]	0.530	1.057	99.267	1.105	108.289	0.532	0.282	1.122	111.529
Other Dairy[e]	9.297	14.196	52.690	15.329	64.875	9.290	-0.079	14.850	59.720
Nova Scotia									
3.5% Milk	0.189	0.189	0.013	0.189	-0.318	0.189	0.000	0.188	-0.571
2% Milk	0.573	0.573	-0.012	0.508	-11.387	0.573	0.000	0.507	-11.507
Low Fat Milk[c]	0.244	0.243	-0.027	0.213	-12.418	0.244	-0.001	0.212	-12.762
Cream	0.070	0.070	0.188	0.079	13.352	0.070	0.004	0.083	19.837
Ice Cream	6.651	8.658	30.169	9.203	38.357	6.646	-0.076	9.108	36.926
Cheddar Cheese	0.960	1.545	61.027	1.623	69.135	0.961	0.112	1.621	68.878
Other Cheese	2.395	3.122	30.357	3.179	32.749	2.397	0.104	3.185	33.006
Butter	2.023	2.556	26.347	2.302	13.800	2.023	0.002	2.216	9.543
Milk Powder[d]	0.183	0.574	214.415	0.703	284.818	0.184	0.576	0.738	303.992
Other Dairy[e]	6.489	10.262	58.135	11.627	79.176	6.484	-0.079	11.284	73.889
New -foundland									
3.5% Milk	0.052	0.052	0.013	0.054	3.678	0.052	0.000	0.054	3.227
2% Milk	0.158	0.158	-0.012	0.135	-14.777	0.158	0.000	0.138	-12.965
Low Fat Milk[c]	0.067	0.067	-0.027	0.052	-22.012	0.067	-0.001	0.055	-18.430
Cream	0.019	0.019	0.188	0.027	38.773	0.019	0.004	0.027	43.332
Ice Cream	0.008	0.007	-14.381	0.008	-7.284	0.008	-0.210	0.008	-8.370
Cheddar Cheese	0.001	0.001	-10.036	0.001	-3.131	0.001	-0.147	0.001	-3.939
Other Cheese	0.003	0.003	-5.529	0.003	-1.858	0.003	-0.059	0.003	-2.604
Butter	0.003	0.003	-1.443	0.003	-3.096	0.003	-0.075	0.002	-14.082
Milk Powder[d]	0.000	0.000	-26.303	0.000	-4.216	0.000	-0.279	0.001	8.807
Other Dairy[e]	0.011	0.008	-21.106	0.010	-9.240	0.011	-0.279	0.010	-10.110

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
and 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. Low Fat milk includes 1% and skim milk.

d. Milk Powder is Skim Milk Powder.

e. Other Dairy is Other Dairy Products.

Table 23. Empirical Results: Provincial Output of Dairy Processed Products (Continued.)

	Scenario[a]								
	1	2		3		4		5	
	Quantity	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]
Ontario									
3.5% Milk	1.70	1.70	0.01	1.92	12.64	1.70	0.00	1.92	12.63
2% Milk	5.16	5.16	-0.01	5.39	4.61	5.16	0.00	5.39	4.58
Low Fat Milk[c]	2.19	2.19	-0.03	2.30	4.88	2.19	0.00	2.30	4.83
Cream	0.63	0.63	0.19	0.65	4.34	0.63	0.00	0.62	-0.24
Ice Cream	155.90	150.76	-3.30	153.36	-1.63	155.58	-0.21	153.50	-1.54
Cheddar Cheese	30.51	30.12	-1.28	30.57	0.21	30.47	-0.13	30.62	0.35
Other Cheese	72.56	72.58	0.04	73.13	0.79	72.53	-0.04	73.31	1.04
Butter	34.40	33.74	-1.94	34.98	1.67	34.36	-0.11	35.18	2.27
Milk Powder[d]	19.09	18.93	-0.86	19.36	1.39	19.06	-0.16	19.11	0.09
Other Dairy[e]	49.21	44.31	-9.96	46.39	-5.73	49.10	-0.24	44.58	-9.42
Quebec									
3.5% Milk	1.18	1.18	0.01	1.38	17.09	1.18	0.00	1.38	17.48
2% Milk	3.57	3.57	-0.01	3.93	10.12	3.57	0.00	3.92	9.92
Low Fat Milk[c]	1.52	1.52	-0.03	1.68	10.88	1.52	0.00	1.66	9.81
Cream	0.43	0.43	0.19	0.45	4.11	0.43	0.00	0.45	3.47
Ice Cream	98.99	90.43	-8.65	92.19	-6.88	98.80	-0.20	92.32	-6.74
Cheddar Cheese	73.29	67.18	-8.34	68.75	-6.20	73.20	-0.12	68.52	-6.51
Other Cheese	126.66	120.73	-4.68	121.97	-3.70	126.60	-0.04	122.25	-3.48
Butter	37.89	34.84	-8.06	36.79	-2.93	37.85	-0.12	36.54	-3.57
Milk Powder[d]	40.57	36.79	-9.30	37.52	-7.52	40.51	-0.14	37.35	-7.94
Other Dairy[e]	54.01	45.40	-15.93	47.54	-11.99	53.89	-0.22	45.92	-14.97

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
and 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. Low Fat milk includes 1% and skim milk.

d. Milk Powder is Skim Milk Powder.

e. Other Dairy is Other Dairy Products.

Table 24. Empirical Results: Dairy Products Prices

	Scenario[a]								
	1	2		3		4		5	
	Price	Price	% change[b]	Price	% change[b]	Price	% change[b]	Price	% change[b]
Canada									
3.5% Milk	0.93	0.90	-2.69	0.66	-28.16	0.92	-0.18	0.65	-30.03
2% Milk	0.87	0.85	-2.47	0.58	-32.85	0.87	-0.18	0.57	-34.53
Low Fat Milk[c]	0.80	0.78	-2.31	0.51	-35.48	0.80	-0.18	0.50	-36.85
Cream	1.99	1.94	-2.57	1.75	-12.06	1.98	-0.15	1.69	-14.72
Ice Cream	2.36	2.28	-3.45	2.32	-1.64	2.35	-0.15	2.21	-6.08
Cheddar Cheese	5.66	5.60	-1.21	5.65	-0.17	5.66	-0.10	5.40	-4.68
Other Cheese	3.55	3.54	-0.37	3.56	0.11	3.55	-0.05	3.45	-3.03
Butter	5.27	5.20	-1.36	5.18	-1.82	5.27	-0.07	5.00	-5.18
Milk Powder[d]	3.74	3.69	-1.27	3.79	1.50	3.73	-0.13	3.56	-4.69
Other Dairy[e]	1.47	1.38	-6.69	1.42	-3.76	1.47	-0.17	1.32	-10.46
Export									
Ice Cream	1.53	1.47	-3.79	1.49	-2.11	1.52	-0.24	1.41	-7.77
Cheddar Cheese	6.65	6.58	-1.01	6.64	-0.07	6.64	-0.09	6.38	-3.97
Other Cheese	5.92	5.91	-0.20	5.93	0.02	5.92	-0.03	5.82	-1.80
Butter	5.52	5.45	-1.32	5.41	-1.98	5.52	-0.07	5.25	-4.96
Milk Powder[d]	5.02	4.98	-0.75	5.08	1.33	5.01	-0.09	4.85	-3.28
Other Dairy[e]	3.12	3.01	-3.50	3.04	-2.61	3.12	-0.08	2.96	-5.28

Unit: $/liter for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
and $/kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and
Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. Low Fat milk includes 1% and skim milk.

d. Milk Powder is Skim Milk Powder.

e. Other Dairy is Other Dairy Products.

Table 25. Empirical Results: Demand Quantities for Dairy Products

	Scenario[a]								
	1	2		3		4		5	
	Quantity	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]
Canadian									
3.5% Milk	4.813	4.849	0.749	5.245	8.973	4.815	0.052	5.274	9.573
2% Milk	14.344	14.377	0.235	14.819	3.313	14.346	0.017	14.843	3.483
Low Fat Milk[c]	6.106	6.119	0.212	6.32	3.493	6.107	0.016	6.328	3.628
Cream	1.753	1.768	0.845	1.829	4.303	1.754	0.049	1.845	5.235
Ice Cream	324.236	333.923	2.987	328.823	1.415	324.67	0.134	341.279	5.256
Cheddar Cheese	113.66	114.484	0.725	113.779	0.104	113.729	0.061	116.85	2.806
Other Cheese	190.39	190.718	0.173	190.292	-0.051	190.43	0.021	193.052	1.398
Butter	84.64	85.435	0.939	85.706	1.258	84.684	0.052	87.666	3.575
Milk Powder[d]	29.036	29.218	0.625	28.821	-0.741	29.054	0.062	29.708	2.313
Other Dairy[e]	171.26	179.49	4.806	175.889	2.703	171.473	0.125	184.136	7.519
Export									
Ice Cream	45.207	46.599	3.081	45.984	1.719	45.295	0.195	48.065	6.324
Cheddar Cheese	6.314	6.372	0.917	6.318	0.066	6.319	0.078	6.541	3.597
Other Cheese	37.068	37.123	0.15	37.062	-0.015	37.075	0.02	37.557	1.321
Butter	12.59	12.738	1.178	12.813	1.771	12.598	0.064	13.149	4.442
Milk Powder[d]	41.96	42.303	0.816	41.353	-1.447	42.003	0.102	43.455	3.562
Other Dairy[e]	7.679	7.906	2.964	7.849	2.213	7.684	0.069	8.022	4.473

Unit: 100,000 Hectoliters for Fluid Products (3.5% Milk, 2% Milk, Low Fat Milk, Cream)
and 1,000,000 kg for Solid Products (Cheddar Cheese, Other Cheese, Butter, Skim Milk Powder and Other Dairy Products)

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. Low Fat milk includes 1% and skim milk.

d. Milk Powder is Skim Milk Powder.

e. Other Dairy is Other Dairy Products.

Table 26. Empirical Results: Provincial Raw Milk Production

	Scenario[a]								
	1	2		3		4		5	
	Quantity	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]	Quantity	% change[b]
Fluid Milk									
British Columbia	3.652	3.652	0.00	3.344	-8.4	3.652	0.00	3.389	-7.19
Alberta	2.840	2.964	4.38	3.087	8.7	2.842	0.08	3.128	10.14
Saskatchewan	1.156	1.156	0.00	1.283	11.0	1.156	0.00	0.959	-17.06
Manitoba	1.243	1.131	-8.99	1.301	4.6	1.243	0.00	1.173	-5.67
Ontario	10.483	10.377	-1.02	10.262	-2.1	10.460	-0.22	10.234	-2.38
Quebec	6.691	6.691	0.00	7.439	11.2	6.691	0.00	7.418	10.85
New Brunswick	0.691	0.649	-6.07	0.591	-14.4	0.691	0.00	0.589	-14.68
P.E.I.	0.210	0.148	-29.46	0.129	-38.7	0.210	0.00	0.130	-38.17
Nova Scotia	1.075	1.075	0.00	0.986	-8.3	1.075	0.00	0.988	-8.14
Newfoundland	0.297	0.297	0.24	0.266	-10.2	0.297	0.00	0.272	-8.26
Canada	28.338	28.141	-0.70	28.688	1.2	28.317	-0.07	28.279	-0.21
Industrial Milk									
British Columbia	1.802	3.226	79.04	2.873	59.5	1.802	0.00	3.379	87.55
Alberta	3.009	2.599	-13.63	2.237	-25.7	3.004	-0.17	2.714	-9.82
Saskatchewan	1.170	1.620	38.43	1.255	7.3	1.170	0.00	1.908	63.05
Manitoba	1.778	2.285	28.48	1.778		1.778	0.00	2.328	30.93
Ontario	14.157	13.887	-1.91	14.854	4.9	14.157	0.00	14.790	4.47
Quebec	21.881	20.078	-8.24	20.485	-6.4	21.854	-0.13	20.413	-6.71
New Brunswick	0.468	0.876	87.17	0.938	100.5	0.468	0.00	0.930	98.78
P.E.I.	0.819	1.289	57.35	1.355	65.4	0.819	0.00	1.345	64.17
Nova Scotia	0.632	0.941	49.01	1.024	62.1	0.632	0.00	1.015	60.59
Newfoundland	9.02E-04	3.62E-05	-95.988	8.46E-04	-6.442	9.00E-04	-0.209	8.43E-04	-6.543
Canada	45.718	46.800	2.37	46.800	2.4	45.685	-0.07	48.822	6.79
Total Milk									
British Columbia	5.453	6.878	26.12	6.217	14.0	5.554	1.84	6.768	24.11
Alberta	5.878	5.591	-4.89	5.350	-9.0	5.875	-0.05	5.871	-0.13
Saskatchewan	2.374	2.833	19.33	2.590	9.1	2.374	0.00	2.926	23.24
Manitoba	3.081	3.483	13.06	3.139	1.9	3.081	0.00	3.570	15.87
Ontario	24.868	24.488	-1.53	25.348	1.9	24.845	-0.09	25.255	1.56
Quebec	28.573	26.769	-6.31	27.924	-2.3	28.545	-0.10	27.830	-2.60
New Brunswick	1.186	1.561	31.59	1.566	32.0	1.186	0.00	1.555	31.15
P.E.I.	1.029	1.437	39.62	1.484	44.1	1.029	0.00	1.475	43.27
Nova Scotia	1.747	2.064	18.14	2.057	17.7	1.747	0.00	2.049	17.30
Newfoundland	0.30	0.30	-0.05	0.27	-10.23	0.30	0.00	0.27	-8.26
Canada	74.49	75.40	1.23	75.94	1.96	74.53	0.06	77.57	4.14

Unit: 100,000,000 Liter

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 27. Empirical Results: Shadow Value of Milk Components ($/Tonne)

	Scenario[a]								
	1	2		3		4		5	
	Value	Value	% change[b]	Value	% change[b]	Value	% change[b]	Value	% change[b]
Butterfat: Fluid Milk									
British Columbia	3493.690	2255.360	-35.45	2761.600	-21.0	3410.367	-2.39	2188.815	-37.35
Alberta	4207.500	4339.270	3.13	4490.390	6.7	4205.605	-0.05	3966.295	-5.73
Saskatchewan	4070.920	3296.710	-19.02	3853.550	-5.3	4067.363	-0.09	3181.184	-21.86
Manitoba	4478.630	4049.000	-9.59	4382.820	-2.1	4474.620	-0.09	3813.158	-14.86
Ontario	3587.660	3554.390	-0.93	3403.970	-5.1	3586.113	-0.04	3185.843	-11.20
Quebec	3718.080	3847.640	3.48	3660.640	-1.6	3716.612	-0.04	3477.411	-6.47
New Brunswick	3546.660	2149.950	-39.38	2434.420	-31.4	3541.763	-0.14	2273.005	-35.91
P.E.I.	4798.660	3833.140	-20.12	3593.540	-25.1	4793.698	-0.10	3524.704	-26.55
Nova Scotia	2740.100	1670.010	-39.05	2100.900	-23.3	2735.219	-0.18	2061.217	-24.78
Newfoundland	5583.300	7810.370	0.40	6965.700	0.2	7105.260	0.27	7105.260	0.27
Solid No Fat: Fluid Milk									
British Columbia	3284.924	2232.548	-32.04	2015.400	-38.7	3168.998	-3.53	1443.512	-56.06
Alberta	792.282	644.362	-18.67	1466.370	85.1	396.104	-50.01	893.550	12.78
Saskatchewan	2564.714	1637.603	-36.15	2159.040	-15.8	2558.048	-0.26	1760.587	-31.35
Manitoba	1833.880	1110.572	-39.44	1734.740	-5.4	1828.682	-0.28	1288.871	-29.72
Ontario	1671.362	1651.229	-1.21	1801.660	7.8	1669.907	-0.09	1894.507	13.35
Quebec	1268.831	1112.472	-12.32	1259.180	-0.8	871.953	-31.28	1336.080	5.30
New Brunswick	3479.545	2163.168	-37.83	2026.410	-41.8	3471.866	-0.22	2100.412	-39.64
P.E.I.	2903.625	1858.870	-35.98	1970.220	-32.2	2895.944	-0.27	1986.461	-31.59
Nova Scotia	82551.46	85207.980	3.22	2113.610	-97.4	3415.285	-95.86	2124.825	-97.43
Newfoundland	2548.699	2547.953	-0.03	65.640	0.0	2152.643	-15.54	583.420	0.23
Butterfat: Industrial Milk									
British Columbia	3493.693	2255.359	-35.45	2761.600	-21.0	3168.998	-9.29	2188.815	-37.35
Alberta	4207.503	4339.265	3.13	4490.390	6.7	792.150	-81.17	3966.295	-5.73
Saskatchewan	4070.921	3296.711	-19.02	3853.550	-5.3	2558.048	-37.16	3181.184	-21.86
Manitoba	4478.634	4048.997	-9.59	4382.820	-2.1	1828.682	-59.17	3813.158	-14.86
Ontario	3587.664	3554.391	-0.93	3403.970	-5.1	1669.907	-53.45	3185.843	-11.20
Quebec	3718.082	3847.636	3.48	3660.640	-1.6	1267.999	-65.90	3477.411	-6.47
New Brunswick	3546.662	2149.953	-39.38	2434.420	-31.4	3471.866	-2.11	2273.005	-35.91
P.E.I.	4798.657	3833.143	-20.12	3593.540	-25.1	2895.944	-39.65	3524.704	-26.55
Nova Scotia	2740.097	1670.013	-39.05	2100.900	-23.3	82587.010	2914.01	2061.217	-24.78
Newfoundland	-	-	-	2360.560	-	2548.689	-	2179.701	-
Solid No Fat: Industrial Milk									
British Columbia	3284.924	1441.657	-56.11	2015.400	-38.65	3410.367	3.82	1047.465	-68.11
Alberta	396.236	644.362	62.62	1466.370	270.08	4205.605	961.39	497.503	25.56
Saskatchewan	2564.714	1637.603	-36.15	2159.040	-15.82	4067.363	58.59	1364.541	-46.80
Manitoba	1833.880	1110.572	-39.44	1734.740	-5.41	4474.620	144.00	892.825	-51.32
Ontario	1671.362	1651.229	-1.21	1710.340	2.33	3586.113	114.56	1498.460	-10.35
Quebec	872.785	1112.472	27.46	1167.860	33.81	3716.612	325.83	940.033	7.71
New Brunswick	3479.545	2163.168	-37.83	1935.090	-44.39	3541.763	1.79	1704.366	-51.02
P.E.I.	2903.625	1858.870	-35.98	1878.900	-35.29	4793.698	65.09	1590.415	-45.23
Nova Scotia	3422.987	2313.382	-32.42	2022.290	-40.92	2735.219	-20.09	1728.779	-49.50
Newfoundland	2152.653	2547.953	18.36	65.640	0.03	0.000	-100.00	583.420	0.27

Unit: $/1000 kg

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

c. The shadow value is defined in terms of $ of net social payoff per tonne of component.

Table 28 Empirical Results: Provincial Welfare Measurement of Dairy Consumers, Processors and Milk Producers

	Scenario[a]												
	(1)	(2)			(3)			(4)			(5)		
	1000$	1000$	$difference	%Change	1000$	$difference	%Change	1000$	$difference	%Change	1000$	$difference	%Change
Producer Surplus : Milk Production													
British Columbia	45960.76	59587.49	13626.73	29.65	53794.41	7833.66	17.04	45640.11	-320.65	-0.70	58987.83	13027.07	28.34
Alberta	45683.25	43002.02	-2681.23	-5.87	40724.95	-4958.30	-10.85	45653.74	-29.51	-0.07	45127.13	-556.11	-1.22
Saskatchewan	20358.32	24674.36	4316.04	21.20	22175.02	1816.70	8.92	20358.32	0.00	0.00	25881.82	5523.50	27.13
Manitoba	23318.41	26831.58	3513.17	15.07	23704.28	385.87	1.66	23318.41	0.00	0.00	27475.64	4157.22	17.83
Ontario	195913.3	192827.09	-3086.28	-1.58	200416.09	4502.72	2.30	195752.91	-160.46	-0.08	199667.70	3754.33	1.92
Quebec	242309.4	226292.36	-16017.08	-6.61	235277.04	-7032.40	-2.90	242066.76	-242.69	-0.10	234478.87	-7830.57	-3.23
New Brunswick	9094.00	12409.46	3315.46	36.46	12551.27	3457.27	38.02	9094.00	0.00	0.00	12465.63	3371.63	37.08
P.E.I.	8604.96	12261.62	3656.65	42.50	12700.02	4095.05	47.59	8604.96	0.00	0.00	12619.94	4014.98	46.66
Nova Scotia	11191.96	13554.50	2362.55	21.11	13654.84	2462.88	22.01	11191.96	0.00	0.00	13593.87	2401.92	21.46
Newfoundland	2016.74	2014.31	-2.43	-0.12	1810.49	-206.25	-10.23	2016.72	-0.02	0.00	1850.21	-166.53	-8.26
Canada	604451.2	613454.79	9003.58	1.49	616808.40	12357.20	2.04	603697.88	-753.32	-0.13	632148.64	27697.43	4.58
Producer Surplus : Dairy Processing													
British Columbia	98548.92	118838.11	20289.19	20.59	107895.99	9347.07	9.49	99990.21	1441.29	1.46	115948.22	17399.30	17.66
Alberta	81614.05	77625.71	-3988.34	-4.89	74427.45	-7186.60	-8.81	81571.39	-42.65	-0.05	81521.51	-92.53	-0.11
Saskatchewan	32996.57	39399.00	6402.42	19.40	35899.54	2902.96	8.80	32995.25	-1.32	0.00	40566.70	7570.13	22.94
Manitoba	42116.58	47658.86	5542.28	13.16	42947.47	830.89	1.97	42115.14	-1.44	0.00	48792.31	6675.73	15.85
Ontario	361807.3	356587.20	-5220.12	-1.44	367971.31	6164.00	1.70	361478.32	-329.00	-0.09	366483.45	4676.13	1.29
Quebec	371527.7	349270.22	-22257.54	-5.99	363664.37	-7863.38	-2.12	371197.43	-330.33	-0.09	362511.60	-9016.16	-2.43
New Brunswick	18469.21	23497.78	5028.57	27.23	23394.96	4925.75	26.67	18469.25	0.04	0.00	23253.98	4784.76	25.91
P.E.I.	15222.95	20869.69	5646.74	37.09	21409.49	6186.54	40.64	15223.47	0.52	0.00	21328.70	6105.75	40.11
Nova Scotia	27658.09	31968.88	4310.80	15.59	31615.65	3957.56	14.31	27658.46	0.37	0.00	31534.56	3876.47	14.02
Newfoundland	4702.14	4701.44	-0.70	-0.02	4485.45	-216.68	-4.61	4702.13	0.00	0.00	4589.46	-112.68	-2.40
Canada	1054663	1070416.8	15753.30	1.49	1073711.6	19048.10	1.81	1055401.0	737.47	0.07	1096530.4	41866.89	3.97

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 28 Empirical Results: Provincial Welfare Measurement (Continued.)

	Scenario[a]													
	(1)	(2)			(3)			(4)			(5)			
	1000$	1000$	$difference	%Change	1000$	$difference	%Change	1000$	$difference	%Change	1000$	$difference	%Change	
Consumer Surplus														
British Columbia	2309897	2320000	10569	0.46	2314410	4513	0.20	2310414	517	0.02	2328596	18699	0.81	
Alberta	1696788	1704551	7764	0.46	1700103	3315	0.20	1697168	380	0.02	1710523	13736	0.81	
Saskatchewan	631783	635000	2891	0.46	633017	1234	0.20	631924	141	0.02	636897	5114	0.81	
Manitoba	705231	708458	3227	0.46	706609	1378	0.20	705389	158	0.02	710940	5709	0.81	
West Total	5340000	5370000	24450	0.46	5350000	10440	0.20	5344895	1196	0.02	5386957	43258	0.81	
Ontario	6547951	6563022	15071	0.23	6607674	59723	0.91	6548767	816	0.01	6635992	88041	1.35	
Quebec	4347834	4360000	10007	0.23	4387491	39656	0.91	4348376	542	0.01	4406294	58459	1.35	
New Brunswick	452527	453569	1042	0.23	456655	4127	0.91	452584	56	0.01	458612	6085	1.35	
P.E.I.	80979	81200	186	0.23	81717	739	0.91	80989	10	0.01	82067	1089	1.35	
Nova Scotia	557919	559203	1284	0.23	563007	5089	0.91	557988	70	0.01	565420	7502	1.35	
Newfoundland	344754	345548	794	0.23	347899	3144	0.91	344797	43	0.01	349390	4635	1.35	
East Total	12300000	12400000	28384	0.23	12400000	112479	0.91	12300000	1537	0.01	12500000	165811	1.35	
Canada	17700000	17700000	52834	0.30	17800000	122919	0.70	17700000	2733	0.02	17900000	209069	1.18	
Export	998999	1005017	6018	0.60	998842	-157	-0.02	999486	487		1018973	19974	2.00	
Total Welfare														
British Columbia	2454407	2498891	44485	1.81	2476100	21693	0.88	2456044	1640	0.07	2503532	49125	2.00	
Alberta	1824085	1825179	1094	0.06	1815255	-8830	-0.48	1824393	308	0.02	1837172	13087	0.72	
Saskatchewan	685138	698747	13609	1.99	691092	5954	0.87	685278	140	0.02	703346	18208	2.66	
Manitoba	770666	782948	12282	1.59	773261	2595	0.34	770823	156	0.02	787208	16542	2.15	
Ontario	7105671	7110000	6765	0.10	7176061	70390	0.99	7105998	327	0.01	7202143	96472	1.36	
Quebec	4961672	4933404	-28267	-0.57	4986432	24760	0.50	4961640	-31	0.00	5003284	41613	0.84	
New Brunswick	480091	489000	9386	1.96	492601	12510	2.61	480147	56	0.01	494331	14241	2.97	
P.E.I.	104807	114296	9490	9.06	115827	11020	10.52	104817	11	0.01	116016	11210	10.70	
Nova Scotia	596769	604726	7958	1.33	608278	11509	1.93	596838	70	0.01	610549	13780	2.31	
Newfoundland	351473	352000	790	0.23	354195	2722	0.77	351516	43	0.01	355829	4356	1.24	
Canada	19300000	19400000	77591	0.40	19500000	154324	0.80	19300000	2717	0.01	19600000	278634	1.44	

Note:

a. Scenario 1 is the initial baseline solution. 2 is the partial national pooling of industrial quota. 3 is regional pooling of Fluid and Industrial milk and quota. 4 is the pooling of special milk classes. 5 is the total removal of MSQ.

b. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 29. Sensitivity Analysis for Demand Elasticity on Dairy Cow Numbers

	Baseline Results	50% of Demand Elasticity			90% of Demand Elasticity			100% of Demand Elasticity			110% of Demand Elasticity			150% of Demand Elasticity		
	Cow Numbers	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change
British Columbia	71.85	86.36	14.51	20.19	88.67	16.82	23.41	89.17	17.32	24.11	89.65	17.80	24.78	91.43	19.58	27.25
Alberta	94.20	90.97	-3.23	-3.43	93.53	-0.67	-0.71	94.08	-0.12	-0.13	94.60	0.40	0.43	96.55	2.35	2.49
Saskatchewan	42.27	50.11	7.83	18.53	51.74	9.47	22.39	52.10	9.82	23.24	52.44	10.16	24.04	53.63	11.36	26.87
Manitoba	52.85	59.46	6.61	12.50	60.89	8.04	15.21	61.24	8.39	15.87	61.58	8.72	16.50	62.75	9.90	18.72
Ontario	379.55	372.63	-6.91	-1.82	383.17	3.62	0.96	385.46	5.91	1.56	387.63	8.09	2.13	395.41	15.86	4.18
Quebec	440.19	414.17	-26.02	-5.91	426.15	-14.04	-3.19	428.75	-11.44	-2.60	431.22	-8.97	-2.04	439.91	-0.28	-0.07
New Brunswick	18.60	23.45	4.86	26.11	24.22	5.63	30.25	24.39	5.79	31.15	24.55	5.95	32.00	25.11	6.51	35.01
P.E.I.	16.38	22.49	6.11	37.26	23.30	6.92	42.21	23.47	7.09	43.27	23.64	7.25	44.27	24.20	7.82	47.72
Nova Scotia	25.17	28.41	3.24	12.88	29.32	4.15	16.51	29.52	4.35	17.30	29.71	4.54	18.06	30.39	5.22	20.76
Newfoundland	4.15	3.68	-0.47	-11.23	3.78	-0.37	-8.82	3.80	-0.34	-8.26	3.83	-0.32	-7.71	3.91	-0.24	-5.66
Canada	1145.21	1151.73	6.52	0.57	1184.78	39.57	3.46	1191.98	46.78	4.08	1198.84	53.63	4.68	1223.28	78.07	6.82

Unit of Dairy Cows: 1000

Note:

a. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 30. Sensitivity Analysis for Supply Elasticity of Milk Processing on Dairy Cow Numbers

	Baseline Results	50% of Supply Elasticity			90% of Supply Elasticity			100% of Supply Elasticity			110% of Supply Elasticity			150% of Supply Elasticity		
	Cow Numbers	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change
British Columbia	71.85	87.07	15.22	21.19	88.83	16.98	23.64	89.17	17.32	24.11	89.77	17.92	24.93	90.46	18.61	25.90
Alberta	94.20	90.99	-3.21	-3.41	93.54	-0.66	-0.70	94.08	-0.12	-0.13	95.07	0.87	0.92	96.34	2.14	2.27
Saskatchewan	42.27	52.14	9.87	23.34	52.12	9.85	23.30	52.10	9.82	23.24	52.06	9.78	23.14	51.95	9.68	22.89
Manitoba	52.85	60.39	7.54	14.26	61.11	8.25	15.62	61.24	8.39	15.87	61.47	8.61	16.30	61.71	8.85	16.74
Ontario	379.55	386.48	6.93	1.83	385.90	6.35	1.67	385.46	5.91	1.56	384.44	4.90	1.29	383.10	3.55	0.94
Quebec	440.19	417.68	-22.51	-5.11	427.01	-13.18	-3.00	428.75	-11.44	-2.60	431.83	-8.36	-1.90	435.45	-4.74	-1.08
New Brunswick	18.60	24.68	6.09	32.74	24.45	5.85	31.48	24.39	5.79	31.15	24.26	5.67	30.48	24.09	5.50	29.56
P.E.I.	16.38	24.61	8.22	50.19	23.68	7.29	44.51	23.47	7.09	43.27	23.09	6.71	40.95	22.60	6.22	37.96
Nova Scotia	25.17	29.77	4.60	18.28	29.58	4.41	17.52	29.52	4.35	17.30	29.41	4.24	16.85	29.25	4.08	16.22
Newfoundland	4.15	4.03	-0.12	-2.81	3.82	-0.33	-7.85	3.80	-0.34	-8.26	3.77	-0.37	-9.03	3.73	-0.42	-10.09
Canada	1145.21	1177.84	32.63	2.85	1190.03	44.82	3.91	1191.98	46.78	4.08	1195.16	49.96	4.36	1198.68	53.47	4.67

Unit of Dairy Cows: 1000

Note:

a. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 31. Sensitivity Analysis for Supply Elasticity of Milk Production on Dairy Cow Number

	Baseline Results	50% of Supply Elasticity			90% of Supply Elasticity			100% of Supply Elasticity			110% of Supply Elasticity			150% of Supply Elasticity		
	Cow Numbers	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change	Cow Numbers	Numbers Change	% Change
British Columbia	71.85	87.07	15.22	21.19	88.83	16.98	23.64	89.17	17.32	24.11	89.77	17.92	24.93	90.46	18.61	25.90
Alberta	94.20	90.99	-3.21	-3.41	93.54	-0.66	-0.70	94.08	-0.12	-0.13	95.07	0.87	0.92	96.34	2.14	2.27
Saskatchewan	42.27	52.14	9.87	23.34	52.12	9.85	23.30	52.10	9.82	23.24	52.06	9.78	23.14	51.95	9.68	22.89
Manitoba	52.85	60.39	7.54	14.26	61.11	8.25	15.62	61.24	8.39	15.87	61.47	8.61	16.30	61.71	8.85	16.74
Ontario	379.55	386.48	6.93	1.83	385.90	6.35	1.67	385.46	5.91	1.56	384.44	4.90	1.29	383.10	3.55	0.94
Quebec	440.19	417.68	-22.51	-5.11	427.01	-13.18	-3.00	428.75	-11.44	-2.60	431.83	-8.36	-1.90	435.45	-4.74	-1.08
New Brunswick	18.60	24.68	6.09	32.74	24.45	5.85	31.48	24.39	5.79	31.15	24.26	5.67	30.48	24.09	5.50	29.56
P.E.I.	16.38	24.61	8.22	50.19	23.68	7.29	44.51	23.47	7.09	43.27	23.09	6.71	40.95	22.60	6.22	37.96
Nova Scotia	25.17	29.77	4.60	18.28	29.58	4.41	17.52	29.52	4.35	17.30	29.41	4.24	16.85	29.25	4.08	16.22
Newfoundland	4.15	4.03	-0.12	-2.81	3.82	-0.33	-7.85	3.80	-0.34	-8.26	3.77	-0.37	-9.03	3.73	-0.42	-10.09
Canada	1145.21	1177.84	32.63	2.85	1190.03	44.82	3.91	1191.98	46.78	4.08	1195.16	49.96	4.36	1198.68	53.47	4.67

Unit of Dairy Cows: 1000

Note:

a. The % change represents the difference in percentage terms, from the baseline scenario result.

Table 32. Sensitivity Analysis for Transportation Cost on Dairy Cow Numbers

	Baseline Results	10% of Unit Transport Cost		50% of Unit Transport Cost		100% of Unit Transport Cost		200% of Unit Transport Cost	
	Cow Numbers	Numbers difference	%Change	Numbers difference	Numbers Change	Numbers difference	%Change	Numbers difference	%Change
British Columbia	71.85	15.13	21.06	16.08	22.38	17.32	24.11	19.16	26.67
Alberta	94.20	0.99	1.05	0.47	0.50	-0.12	-0.13	-2.01	-2.14
Saskatchewan	42.27	10.30	24.35	10.13	23.96	9.82	23.24	9.11	21.55
Manitoba	52.85	9.39	17.76	8.89	16.83	8.39	15.87	7.91	14.97
Ontario	379.55	3.05	0.80	4.67	1.23	5.91	1.56	7.62	2.01
Quebec	440.19	-5.96	-1.35	-8.63	-1.96	-11.44	-2.60	-15.47	-3.51
New Brunswick	18.60	5.51	29.64	5.62	30.21	5.79	31.15	6.22	33.47
P.E.I.	16.38	7.18	43.85	7.14	43.55	7.09	43.27	6.99	42.68
Nova Scotia	25.17	3.90	15.51	4.08	16.19	4.35	17.30	5.06	20.09
Newfoundland	4.15	-0.45	-10.76	-0.41	-9.81	-0.34	-8.26	-0.17	-4.03
Canada	1145.21	49.04	4.28	48.02	4.19	46.78	4.08	44.42	3.88

Unit of dairy cow: 1000

Note:

a. The % change represents the difference in percentage terms, from the baseline scenario result.

Chapter 8 Conclusions

In recent years, many have considered a move towards freer inter-provincial trade in the Canadian dairy industry as one of crucial steps necessary to improve the sector's overall performance. It is expected that changes to inter-provincial barriers would have significant implications for Canadian dairy producers, processors, and consumers. This study's principal objective is to investigate the economic impact of the adjustment of the supply management system and the removal of inter-provincial trade barriers on the Canadian dairy industry, including producers, processors and consumers.

8.1 Summary of Model

To examine the economic impact of an adjustment to the supply management system and the removal of inter-provincial trade barriers in the Canadian dairy industry, a multi-product, multi-level, and multi-regional quadratic spatial equilibrium mathematical model is adopted for use in this study. Specially, the Canadian Regional Agricultural Model (CRAM) is used.

Since the marginal cost for raw milk production is not easily observed under the supply management system in Canada, marginal cost information for raw milk at the production level and for dairy products at the processing level is not incorporated in most models of the Canadian dairy industry. This study provides a methodology to estimate the unobservable marginal cost of milk production. In this study, Positive

Mathematical Programming is applied to recover the marginal cost estimates from average cost information. The marginal costs estimated in this method show consistency with calculations from a traditional capital pricing model. By obtaining the estimates of marginal costs for both milk producers and processors, the model incorporates upward supply curves for these two levels of the dairy sector.

The usefulness of the resulting model is illustrated in the context of a regional analysis of the Canadian dairy sector. Based on data from the base dairy year of 1995, the updated and enhanced version of CRAM generates reasonable predictions of 1995 dairy production and demand estimates. This result suggests that the proposed modeling approach provides a reasonable approximation of the real world.

8.2 Summary of Empirical Results

Several dairy policy scenarios based on reduction or elimination of inter-provincial restrictions are simulated. The total welfare of the Canadian dairy industry increases in each of the scenarios. At the provincial level, the total welfare in each scenario increases in most provinces. For all the scenarios of inter-provincial trade liberalization, consumers always gain from removal of barriers.

For the scenario involving the partial national pooling of industrial quotas, the trade restriction on industrial milk quotas is partially removed, and a national pool of industrial milk quotas is established. The provincial level production of industrial milk as well as processed industrial products is impacted by this policy change. Dairy farmers and dairy processors in most of the provinces (except Quebec, Ontario and Alberta) gain from this scenario. After the pooling of industrial milk quotas, the total movement of industrial dairy products among provinces tends to be reduced. The welfare measurements show that, in general, total welfare (i.e., including the producers' surplus for the entire agriculture sector and the consumers' surplus for all of the agricultural products) is expected to increase by $40 million (or 0.13%) from the baseline after the pooling of industrial milk quotas. The net welfare in most of the provinces increases after this policy change. Quebec is the only province whose net welfare change is negative (-0.45%).

The second scenario involves regional pooling of industrial and fluid milk quotas. The results suggests that, in general, national welfare is expected to increase by $60 million (or 0.21%) under this scenario. Because of the decrease in prices for processed products at the national level, consumer surplus increases in each province. On the producer side, dairy farmers and dairy processors gain in most of the provinces except Alberta and Quebec. Alberta is the only province whose net welfare change is negative (-0.34%).

In the special milk class pooling scenario, the milk used in products for export as well as milk produced over-quota falls into a special milk class (Class 5) that is priced according to an export price. The empirical results show no significant change for the Canadian dairy industry. Neither the milk production nor exportation of dairy products displays a significant change at the export price level modeled for the scenario.

In the final scenario, the restrictions for milk marketing quotas and inter-provincial restrictions on dairy product movement are removed. No significant increase occurs in total milk production. The total national milk production increases by 4.14% or 3.09 million hectoliters. National dairy cow numbers increase by 4.08% (or 46,775 head). The implication is that the current national milk quota is slightly lower than the actual domestic demand for dairy products. Consumers in all the provinces gain from removal of the supply management in the Canadian dairy industry. The prices of fluid dairy products decrease by approximately 34% at the national level. The prices of industrial dairy products decrease by approximately 5% at the national level. Consumers' surplus and producers' surplus for both dairy farming and processing increase in most of the provinces. Alberta and Quebec have small decreases in welfare for dairy processing. At a provincial level, the net welfare increases in all provinces.

8.3 Conclusions

The principal objective of this study was to investigate the economic impact of the adjustment of supply management system and the removal of inter-provincial trade barriers in the Canadian dairy industry. After identifying scenarios that represent current and proposed policy options and applying the empirical partial spatial price equilibrium model to simulate and examine the impact of each policy scenario on the Canadian dairy industry, this study has reached the following conclusion. The interregional trade barriers in the Canadian dairy industry do slightly distort the allocation of dairy production and processing. The partial or total removal of interregional trade barriers will improve the efficiency of resource allocation but will not tremendously affect the domestic production and consumption of dairy products. The total welfare of the Canadian dairy industry increases in each scenario of interregional trade liberalization. For all the scenarios of inter-provincial trade liberalization, the consumers gain from removal of the barriers. When all of the marketing quotas and inter-provincial barriers are removed, total welfare of consumers in the model increases by $209 million, compared with the baseline welfare level. After removal of the quotas, the welfare for both milk producers and milk processors is expected to increase in most provinces, with Quebec and Alberta being the exceptions. However, the producer surplus for both milk production and milk processing are expected to increase at the national level due to the increase in total production of raw milk and processed dairy products. The total welfare of the Canadian dairy industry increases by 1.39% or $267 million compared with the baseline level after removing quota restrictions that limit inter-provincial trade in the Canadian dairy industry within CRAM.

8.4 Limitation and Implications for Further Studies

The empirical results suggest that the approach used in this study can provide valuable insights into the analysis of spatial and vertical resource allocation in the presence of non-market goods and government intervention. However, this model can still be improved in many ways. Some of the model limitations were addressed in the previous chapter. A few others are noted here.

The availability of data provides the greatest challenge in this study. The improvement of the quality and quantity of Canadian dairy industrial statistics, especially at the provincial level, will certainly improve the ability of any model to accurately represent the real world. For example, although the output of dairy products is available for some provinces (e.g., Ontario, Quebec, and Alberta) from Statistics Canada, for most of the small provinces these data are not available due to confidentiality reasons. Provincial data for most of the final dairy markets (e.g., provincial consumption data for dairy products or provincial retail price) are also not available. Only the national average price and consumption quantity can be used for each province. This problem may not accurately reflect provincial differences and may cause deviations from reality in model results.

In this study, both supply and demand regions are represented by a single fixed geographic point in the model. This practice is a source of deviation from the real world. For example, the supply region in this study is represented by a fixed point (e.g., the major city of each province) in each province. This assumption may affect solutions of some scenarios. Ideally, the more representative points in each region, the better the model reflects reality.

In the Canadian dairy industry, there is storage of processed dairy products. However, a static model cannot reflect this operation. The model used in this study is a static model that cannot reflect parameter change over time. Therefore, a dynamic mathematical programming model would more accurately reflect reality.

Since this study is focused mainly on domestic trade liberalization, the impact of international trade is not incorporated in the model. The Canadian dairy industry is a relatively closed economy in the model. The world market is simplified as a place to dispose of extra dairy products such as butterfat and skim milk powder. Although several studies indicate that the effect of international trade liberalization on the Canadian dairy industry is likely to be small (Meilke et al. 1998), a better representation of the world market would improve the ability of the model to represent reality. One possible improvement in the future would be to incorporate demand-and-supply relationships for the rest of the world or at least a demand relationship for imports from the United States. Incorporating more representative points of the world dairy market would be another way to improve the performance of the model to react to the world market.

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Appendix A: Marginal Cost Calculated from Capitalization Price Model

A capitalization price model is a common instrument for estimating the value of a quota (Barichello, 1995; Moschini and Meilke, 1988; Veeman and Dong, 1995). In this section, a capitalization model is used as an alternative method to obtain the marginal costs from quota values in order to compare them with the results from Positive Mathematical Programming. According to the this model, the capitalized quota value is equal to the sum of the discounted future returns; that is,

$$V = \frac{(P - MC)}{i}, \tag{A-1}$$

where

V is the current capital value of the asset - milk quota;

P is the market price;

MC is the marginal cost of raw milk production;

i is the the relevant discount rate.

Since expected capital gains, interest rates, planning horizons and the degree of risk inherent in the asset are unknown, the choice of a discount rate is largely arbitrary. To obtain the rental value of a quota from the capitalized value, a common practice is to multiply the unused quota price by the prevailing interest rate. Both approaches treat marketing quota as a capital asset providing a stream of annual returns and use the capital asset pricing model to determine the rental value. Albon (1979), Barichello (1981, 1984), and Veeman (1982) obtained the rental value by multiplying the capitalized value of the quota by a discount factor. The choice of an appropriate discount rate is crucial to this approach. In order to calculate the marginal cost of milk production, three types of data are collected: discount rates (CANSIM Matrix 2560), quota values (Agriculture and Agri- Food Canada), and milk prices (Statistics Canada, 1996b). The calculated marginal costs of milk production by provinces are presented in **Error! Reference source not found.**.

Table 33. Marginal Cost Estimates of Milk Production and Quota Value by Province, 1995

Province	Average Milk Price ($/liter)	Average Quota Value ($/liter per day)	Average Interest Rate	Marginal Cost ($/liter)
Newfoundland	-	-	5.76	-
Prince Edward Island	0.50	0.079	5.76	0.35
Nova Scotia	0.57	-	5.76	-
New Brunswick	0.58	0.076	5.76	0.43
Quebec	0.52	0.098	5.76	0.30
Ontario	0.55	0.104	5.76	0.36
Manitoba	0.52	0.065	5.76	0.40
Saskatchewan	0.53	-	5.76	-
Alberta	0.53	0.058	5.76	0.40
British Columbia	0.56	0.073	5.76	0.44

Source: Interest rate is "the bank rate of Canada " from CANSIM (B14006), Milk price from Dairy Market Review (1996), Quota exchange price comes from personal contact with Agriculture and Agri- Food Canada.

Appendix B : Processing Cost Calculated from Revenue Share

Suppose the objective of dairy processing firms in each province want to maximize their profit:

(B-1) $$\text{Max: } \pi = \sum_{i=10} p_i y_i \ - \ \sum_{i=10} w_i x_i$$

where p_i is output price for processed dairy product y_i; w_i is input price for the variable input x_i. If it is assumed that the dairy processing industry in each province is multi-product by nature, faced with allocable variable production factors, and is non-joint in products, then the first order condition is:

$$\partial\pi/\partial x_i = p_i\,(\partial y_i/\partial x_i) - w_i = 0 \text{ or } \partial y_i/\partial x_i = w_i\,/\,p_i$$

According to the definition of homogeneous returns (Beattie and Taylor 1985, p. 40),

$$(\partial y_i/\partial x_i)/(y_i/x_i) = \varepsilon$$

where ε is the scale elasticity.

Therefore

$$p_i\ y_i \ = \varepsilon(\ w_i\ x_i)$$

Therefore the revenue share is

$$(p_i\ y_i)/\sum_{i=10} p_i\ y_i = \varepsilon\ (\ w_i\ x_i)\ /\ \sum_{i=10} \varepsilon(w_i x_i)$$

$$= (\ w_i\ x_i)\ /\ \sum_{i=10} w_i x_I,$$

which is equal to the cost share given the three assumptions noted above.