AN ECONOMIC ANALYSIS OF PRODUCT QUALITY WITHIN THE CANADIAN DAIRY INDUSTRY

By

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B. Sc. (Food Science Engineering) ITESM CQ, Mexico, 1999

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

In

THE FACULTY OF GRADUATE STUDIES
Agricultural Economics

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

July 2004

Library Authorization

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Title of Thesis: An Economic Analysis of Product Quality within the Canadian Cheese Industry

Degree: Master of Science Year: 2004

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ABSTRACT

Dairy production often occurs in distorted, highly protected environments, which affect both the price and quality of the end product. Current Canadian regulations serve to protect the local dairy industry with production quotas and high import tariffs. By raising the price of milk, these regulations may induce Canadian cheese manufacturers to find ways to substitute away from Canadian milk inputs to lower costs and maximize profit. Given that some alternative ingredients can be imported without tariffs, it is natural to examine the link between protective policies for Canadian milk and the quality of processed milk products such as cheese.

Along with the regulations, other changes have occurred in the Canadian cheese processing industry. The structure of the Canadian dairy processing industry has undergone a significant rationalization process in the last decade. The shift into fewer and larger plants has been necessary to achieve the efficiency level and economies of scale to remain competitive. Over the past decade, technological change has induced processors to substitute alternative inputs for the traditional ingredients, which in turn has affected the quality of final products such as cheese.

There has been a great deal of research on the price and efficiency effects of Canada's supply management system for dairy production, but little (or no) work has been done on the effects of supply management on the quality of processed milk products at the consumer level. I develop a theoretical and empirical model to examine the effect of Canadian regulations, technological change and industry consolidation on cheese quality. The analysis helps explain current quality trends in the Canadian cheese and dairy industry, as well as the social cost of Canadian supply management in milk products.

This thesis uses theoretical and empirical analysis to examine the effects of supply management on quality in the dairy industry, thereby filling a gap in the literature. Specifically, for the theoretical model I examine the effect of supply management on cheese quality, quantity produced and number of firms in the industry using some comparative statics analysis. For the empirical model, I use the derived demand equation for casein as a function of the reduced form demand for the outputs (cheddar, specialty cheese, yogurt and ice cream), the marginal costs (milk price, wage and metal) and the number of plants to determine the effect of high levels of protection on product quality.

Most of the empirical results match the theoretical ones. In both models, evidence suggests that supply management negatively affects cheese quality. In the theoretical model, supply management, by increasing marginal costs, increases the quantity of extended cheese produced. In the empirical model, the quantity of casein imports increases in response to an increase in the price of milk. The results of the empirical model suggest that approximately 9.8% of specialty cheese is produced using casein. Furthermore, I estimate the amount of milk displaced by casein if milk price increases one dollar, 722.65 hl of milk per month; and the implied spillover effect on Canadian dairy farmers, which, on average, decreases their rents by 33,033 dollars per month.

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ASM	Annual Survey of Manufactures
CAD	Canadian Dollar
CANSIM	Canadian Socioeconomic Information Management
CDC	Canadian Dairy Commission
CEM	Commercial Export Milk
CITT	Canadian International Trade Tribunal
CPI	Consumer Price Index
DFAIT	Department of Foreign Affairs and International Trade
GATT	General Agreement on Tariffs and Trade
IPI	Industrial Price Index
LFS	Labour Force Survey
MCP	Multiple Component Pricing
MPC	Milk Protein Concentrates
MSQ	Market Share Quota
NAICS	North American Industrial Classification System
OEP	Optional Export Program
SIC	Standard Industrial Classification
TRQ	Tariff Rate Quota
U.S.	United States
USD	United States Dollar
USDA	United Stated Department of Agriculture
WTO	World Trade Organization

ACKNOWLEDGEMENT

I am particularly grateful to Kathy Baylis, my advisor, without whom this project would not have been completed. Special thanks to Tim Beatty, the supervisor of this program and initiator of the project.

I would like to thank all the other members of my thesis and examination committees, Tom Ross, Jim Vercammen and Sumeet Gulati for their comments and assistance. Thanks to the people at Agriculture and Agri–Food Canada, Mike Trant, David Surprenant, Mario Casavant, Roger Heard, Michel Britten and Sharan Rakhra; Mary Luebbe at the UBC Library; and all the people who helped me get data and information for this thesis.

I also thank all my friends and colleagues in the FRE and ECON departments. Special thanks to Kristyn and Gmelina for all their help in the proofreading and editing of my thesis and presentations.

Most of all, I would like to thank my parents for their endless love and support.

INTRODUCTION

Dairy production often occurs in distorted, highly protected environments, which affect both the price and quality of the end product. In Canada, high import tariffs, implemented in conjunction with a supply management policy, provide support for dairy farmers and increase the price of milk to processors[1]. Over the past decade, technological change has induced processors to substitute alternative inputs for the traditional ingredients, which in turn has affected the quality of final products such as cheese. Because some alternative ingredients can be imported without tariffs, it is natural to examine the link between protective policies for Canadian milk and the quality of processed milk products such as cheese. This thesis uses theoretical and empirical analysis to examine this linkage.

There has been a great deal of research on the price and efficiency effects of Canada's supply management system for dairy production, but little (or no) work has been done on the effects of supply management on the quality of processed milk products at the consumer level. I develop a theoretical and empirical model to examine the effect of Canadian regulations, technological change and industry consolidation on cheese quality. The analysis helps explain current quality trends in the Canadian cheese and dairy industry, as well as the social cost of Canadian supply management in milk products.

Production quotas and high import tariffs have raised the price of milk for Canadian cheese manufacturers, thereby causing these firms to search for ways to substitute away from national milk inputs. According to the Canadian Dairy Commission, processors are reducing costs in an increasingly consolidated industry by replacing domestic dairy ingredients with less expensive imported ingredients, even though they pay a special (world) price[2] for domestic dairy ingredients. These trends have been exerting considerable competitive pressure on the Canadian dairy industry in recent years. This competitive pressure may have led to a greater use of extenders[3]. A vital research question is whether this trend has been exacerbated by supply management.

The dairy industry provides an important illustration of how trade barriers, subsidies and international trade agreements can influence production decisions in a domestic market. Whereas milk, cheese and other traditional dairy products face prohibitive import barriers, some ingredients that replace milk in dairy products, such as casein (the main protein in milk), butteroil–sugar blends and some milk protein concentrates, are not subject to import tariffs in Canada. Canadian dairy producers argue that dairy ingredients and substitutes entering the country without effective tariffs undermine the supply management system (Task Force on National Dairy Policy, 1991 and Wilson, 2003). For example, butteroil–sugar blends are able to circumvent the import tariffs on dairy products, making it possible for importers to access cheap butteroil. After importation, butteroil is separated from the sugar and used in ice cream manufacturing, thereby competing with domestic cream and butter. Butteroil is also used in bakery and confectionary products and, thus, it competes with other national dairy ingredients. These substitution possibilities have been an important issue for the Dairy Farmers of Canada, since around 30% of ice cream production in Canada is now produced using butteroil.

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[1] In this context, producer is the farmer and processor is the manufacturer.
[2] The world price is lower than the domestic, for example, in Quebec in December 1996, the price for milk used to produce cheddar cheese (domestic price) was 51 dollars/hl, the price for milk used in cheese for further processing (based on U.S. milk price) was 34.91 dollars/hl, and the price for milk used in products for the export market (based on world market milk price) was 27.20 dollars/hl.
[3]Extenders are mixes of functional ingredients such as dairy ingredients (skim milk powder, whey, whey protein concentrates, casein, caseinates, etc), starch, gums, stabilizers, enzymes and sometimes flavours.

This thesis develops a theoretical framework to address the issue of cheese quality and an empirical analysis of dairy products. With the theoretical model, I examine the effect of supply management on cheese quality, quantity and number of firms using comparative statics analysis. The empirical component examines the derived demand for casein as a function of the demand for all products (outputs), the marginal costs and the number of plants. Specifically, I test whether casein was used as a substitute for milk and therefore the higher price of milk increased its use. I also test whether casein use increased with consolidation in the dairy processing industry.

The first chapter describes the relevant literature. Chapter two describes the Canadian cheese industry. In chapters three and four, I present the development of a theoretical model followed by the empirical model. Chapter five discusses the results, while chapter six concludes.

1. LITERATURE REVIEW

There have been a number of studies on the effects of both supply management and the high level of protection of the Canadian dairy industry. Previous theoretical studies on productivity conclude that Canadian dairy producers will be at a disadvantage if import protection is removed because of overinvestment (Richards, 1996), slower adjustment rates, lower rates of productivity growth and loss of competitiveness with dairy producing industries in countries without supply control (Richards and Jeffrey, 1997). As a result of all of these factors, the producing sector has higher costs which translate into higher prices for raw milk.

From the literature dealing with costs, Barichello and Stennes (1994) find in their theoretical analysis that provincial average farm costs for Ontario and Quebec were approximately fifty percent higher than analogous costs in California. The authors note that variable costs were similar when cost sub–components were examined, but the comparison depends on scale. Additionally, they find that most of the cost differences between the United States and Canada correspond to differences in herd size and yield per cow. As a result, raw milk prices are higher in Canada than in the United States.

Barichello (1999) suggests, in his theoretical research, that Canadian farmers and processors could be competitive with the United States, but only if the value of the Canadian dollar remains low relative to its U.S. counterpart, the costs for raw milk are comparable across the border and there is new capital investment in processing plants. These studies show that Canadian farmers, to be competitive with the United States, will need to make changes under the current supply management system.

Other theoretical studies show that the Canadian dairy industry may be able to compete with the United States if supply management ended. Vercammen and Schmitz (1994) show that, once production and import controls are eliminated, fewer rather than more imports may enter the country. The reason for this counter–intuitive result is that supply management allows importers to earn great profits, whereas the producers themselves would be able to produce at similar cost to their U.S. counterparts. Meilke, Sarker and Le Roy (1988) obtain a similar result. They conclude that net trade between Canada and the United States under free trade will be small or zero. They argue that current quota holders will experience large welfare losses, which will be offset by the welfare gains of new entrants. Barichello (1999) confirms these findings. Thus, although the persistence of supply management and its high level of protection have created rents for producers, by raising the price of raw milk, it may also be creating a demand for low–cost milk–substitutes.

In regards to international trade, a theoretical study by Brander and Spencer (1984), which assumes imperfect competition, shows that countries have an incentive to subsidize exports of industries with market power to improve domestic profit and allow the domestic firm to increase market share. Thus, a country like Canada may see net welfare benefits by subsidizing industries where there is some form of imperfect competition, such as the dairy industry. Even if the country would benefit from cooperation with other countries and would agree not to use export subsidies, the incentive to cheat is always present. They suggest that international agreements such as the General Agreement on Tariffs and Trade (GATT) will need regular enforcement to succeed. In 2000, Canada was required by the World Trade Organization (WTO) to eliminate subsidies on dairy products.

Whether the tariffed good is a final product or an input changes the distribution of rents. Ishikawa and Spencer (1996) argue in their theoretical study, that export subsidies that are supposed to increase rents for the producers of the final good may also shift rents to foreign firms who supply intermediate goods, assuming Cournot competition for both goods. They note that if the intermediate good only comes from imports, an export subsidy to the final good is equivalent to an import subsidy to the intermediate good set at the same level. This means that the suppliers of the intermediate good capture all of the rents associated with an export subsidy. In a case like the Canadian dairy industry, this result would imply that the export subsidies would largely (or wholly) benefit input suppliers, which include importers of dairy extenders. Thus, Canadian dairy farmers have reason to think that dairy ingredients entering the country without the adequate tariffs may have captured some of the rents intended to benefit Canadian dairy processors and farmers.

Several studies have looked at the effect of supply management on market structure. A substantial downward trend in the number of Canadian processing plants has been observed over the last decade. According to the theoretical study by Romain (2001), there have been structural adjustments in Canadian dairy processing that are independent of supply management. Because of the quota system, these structural changes have tended to be slower and less important than in the United States, making the Canadian dairy sector (producers and processors) relatively less competitive.

Rude and Goddard (1995), in their empirical study, find evidence that suggests that the processing sector has a significant degree of market power and that they operate with increasing returns to scale. Schmitz and Schmitz (1994) find no evidence in their theoretical study to support the claim that supply management has reduced processor and retailer market power. They find that there appears to be little relationship between farm gate price, the wholesale price and the retail price. Thus, even though there is some evidence that supply management may have slowed consolidation, there is evidence of market power in Canada's dairy processing and retail sector.

The effect of supply management on income distribution has also been widely studied. The direction of the income flow is from consumers and tax payers to farmers generating a net social cost. The amount transferred depends on the estimation method and it is not identified within the sector (Schmitz and Schmitz, 1994). Barichello (1996) finds in his theoretical study that supply management, by protecting domestic production, increases production rents. In what follows, I find evidence that there is a spillover effect of supply management that increases input substitution away from domestic milk, which decreases the revenue created by supply management.

To the best of my knowledge, this is the first study to look at the effect of supply management or market power in the dairy industry on product quality. However, a somewhat related study examines the consequences of allowing the sale of reconstituted fluid milk in the United States (Whipple, 1983). This study finds that, as a result of allowing this new technology, prices have fallen, thereby causing quantity of fluid milk produced and total producer revenue to fall as well. Although total fluid milk consumption will increase because of the lower price, the net effect is a decrease in total expenditure. The results obtained in Whipple (1983) are similar to my theoretical results.

2. BACKGROUND ON THE CANADIAN CHEESE INDUSTRY

Regulations in the Canadian dairy industry increase the price to processors. Technological change has given processors the option of substituting alternative ingredients in their production. This chapter contains a brief summary of the regulations (supply management), and the technical and industry background.

2.1 Supply Management[4]

Supply management raises milk price. There have been many regulations to deal with the fact that the increased milk price will make Canadian processors less competitive, such as the industrial milk subsidy and several export subsidies and programs. All of these have been ruled as violating the GATT and have subsequently been removed. However, while in place, they affected the relative price of inputs, and hence presumably affected the demand for extenders. Therefore, to understand the evolution of cheese quality in Canada, we need to review these rules.

Since 1890, the federal government has been actively involved in the support of the dairy industry. Presently, the Canadian Dairy Commission (CDC) is responsible for the development and implementation of Canadian dairy policies and programs. The CDC was established in 1966 under the Canadian Dairy Commission Act. The Commission's objectives are to stabilize prices for producers, processors and consumers, provide producers with returns that cover their cost of production and ensure an adequate supply of dairy products to

[4] See Appendix I for a flowchart of the Supply Management System.

consumers. To meet these objectives, the supply management system was implemented in the early seventies (CDC, 2003). The three main elements of the supply management system are production quotas, support prices and import controls.

The CDC sets a national quota of industrial milk based on butterfat self–sufficiency (CITT, 1998). This quota is allocated to the provinces based on historical shares at the time supply management was introduced: this allocation has remained virtually fixed over time (Romain, 2001). In 1997, Quebec had 46.6% of the industrial milk quota (called Market Share Quota, MSQ) and Ontario had 31.5% (CDC, 2003). Individual processors can buy or sell, at market determined prices, their quota at monthly auction sales overseen by provincial boards or agencies (Canadian Dairy Industry Profile, 2002).

In 1975, a Returns Adjusted Formula was used to determine the support price for butter and skim milk powder. This formula used the consumer price index, the dairy cash input price index and judgment factors to obtain a fair return for farmers (Barichello 1981). To achieve the desired price, the government used a combination of direct subsidies and support prices. In 1988, this formula was replaced by a more accurate price mechanism that exclusively captured the cost production information at the farm level (based on provincial surveys).

The pricing system has 5 principal components: the target price, the direct subsidy to producers, the margin for dairy processors, the end product support prices and the provincial farm gate prices (Task Force on National Dairy Policy, 1991). The CDC is in charge of establishing the target and support prices based on advice received from the industry, cost of production, market conditions and the general state of the Canadian economy (CITT, 1998).

According to the CDC Act, the target price should be adequate to cover costs and allow producers to earn a fair return on their labour and investments. Support prices for butter and skim milk powder include the manufacturing margin obtained by processors. This margin is assumed to cover costs of production and provide a fair return[5]. As part of the target price, the federal government used to give direct monthly payments to the farmers for deliveries of industrial milk and cream to meet domestic demand (Task Force on National Dairy Policy, 1990). This subsidy was phased out between February 1998 and February 2002 because of WTO commitments. The support prices went up to allow producers to recover from the subsidy elimination (CDC Annual Report, 2001-2002).

From 1990 to July 1995, the CDC used two initiatives to improve the competitive position of the Canadian dairy processors. These initiatives were a rebate to further processors[6] to try to increase the use of domestic dairy ingredients and levies collected from producers to finance the exports of dairy products realised by the CDC (CDC, 2003). Further processors were eligible to receive the equivalent of 60% of the difference in raw milk prices between Canada and the United States if they demonstrated loss of market share to an imported product. In 1993, the rebate increased to cover 85% of the price gap. There were three types of levies: the in–quota levy, a fluid skim–off levy (dropped in 1993) and the over–quota levy. The in–quota levy is determined by the differential between world and domestic dairy prices, the level of Canadian exports and the other programs financed by this levy (Ewing, 1994).

[5] According to the Task Force on National Dairy Policy (1991), the CDC uses the results of the cost of processing study to calculate the margin for dairy processors.
[6] Further processors are those processors whose inputs are already processed dairy products, that is, cheese, skim milk powder, etc.

In August 1995, a new pricing and pooling system, the Harmonized Milk Classification System[7], was established. The Harmonized system classifies industrial milk in relation to its end use. Prices and allocation of industrial milk vary according to the corresponding milk class.

This system includes special (competitive) prices for further processing. These special classes were created to allow Canadian products to compete internationally. Currently, the special classes include cheese (class 5a), other dairy products for further processing (class 5b), dairy ingredients for confectionary (class 5c) and planned exports (class 5d) (CDC, 2003). The Canadian Dairy Commission calculates the prices for special classes 5a and 5b based on the U.S. milk and dairy product prices. The price for special class 5d is based on world market prices and other factors (Milk Ingredients, 2003). The prices for class 5c (dairy ingredients used in confectionery) are determined based on agreements between the dairy and confectionery industries (Emmons and Modler, 2000). During the 1996/1997 dairy year, 8% of the MSQ was provided under the special class 5 (CITT, 1998).

Processors need a special permit to obtain the prices for the special classes. In the dairy year 1996/1997, 532 companies obtained permits for the special classes, using an equivalent of 5% of the total amount of milk produced in that year (CITT, 1998). There are 3 kinds of permits issued by the CDC. The first permit type relates to dairy products for further processing. It is issued through class 5a for cheese used as an ingredient, class 5c for dairy ingredients in the confectionery division and 5b for all other dairy products used as ingredients. The second permit type concerns exports and it is issued under class 5d. This permit specifies the quantity of dairy products to be exported according to the volume of milk

[7] See Appendix II for the definition of the actual classes.

available under planned exports (incorporated into MSQ). This quantity is part of Canada's WTO commitment levels. The third permit type is issued through class 4m and allows the surplus milk of this class to be sold to animal feed manufacturers. To obtain these permits, further processors have to prove that foreign imported products similar to their own constitute an injury or threaten to injure their sales. Distributors that sell ingredients to Special Milk Class Permit holders are eligible to receive the special prices (Milk Ingredients, 2003).

The provincial authorities use the target prices for each milk class and the support prices for butter and skim milk powder as a guide to determine the actual milk price paid to producers. That said, each province can use its unique cost at the farm and processor level to set a price slightly different than that suggested by the target and support prices (see Figure 2.1). However, the milk classes are the same across all provinces.

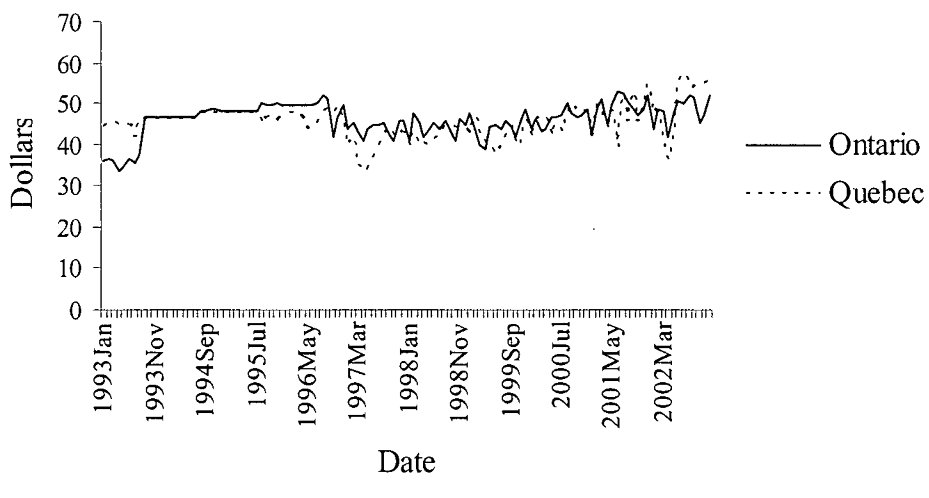

Figure 2.1: Weighted Average Price over Time for Ontario and Quebec

As part of the Offer to Purchase Program, the CDC bought the surplus production of butter and skim milk powder at the support prices. In the late–nineties, due to WTO negotiations, this program was modified and now consists of a surplus removal program and butter, concentrated milk and skim milk stocks programs. The surplus removal program consisted of two parts. In one part, processors exported their surplus production directly through the milk class 5e. In the other part, the CDC bought the surplus at world market prices and charged a levy on producers to cover the cost of disposal. The butter, concentrated and skim milk stocks programs were used to balance the seasonality of these products (CITT, 1998).

Another program, the Optional Export Program (OEP), was also established as a consequence of WTO negotiations. Implemented in August 1995, the OEP allowed processors, exporters and producers to participate in the export market. The provincial boards and agencies were in charge of determining all the guidelines for this program. Individual producers were allowed to use up to 10% of their quota and provinces up to 5% of their total production in this program (CITT, 1998).

The CDC is no longer exporting products directly. The exception is some surplus removal that is sold to the Cuban and Mexican governments. Now producers have to limit their exports using the class 5d permit (CDC, 2003). Canada eliminated class 5e in August 2000 and transformed the Optional Export Program into the Commercial Export Milk (CEM) system as part of WTO commitments of 1999 (Annual Dairy Trade Bulletin, 2001).

The Commercial Export Milk system was implemented in July/August 2000 to deregulate milk intended for exports. This system is independent of Canada's domestic marketing system. The price and quantity of milk, as well as the contracts, are determined by the processors' demand and producers' supply of milk. In Manitoba, Ontario and Quebec, CEM transactions are made through electronic bulletins, while in the other provinces transactions occur directly between buyers and sellers (Annual Dairy Trade Bulletin, 2001). However, on December 20, 2002 the WTO ruled that the CEM system constituted an export subsidy (Canadian Dairy Industry Profile, 2002). With the export program, the processors had access to less expensive milk. For exports to continue, costs must be kept low after the elimination of the program. One cost reducing option is to switch technology and produce extended cheese. Another option is to reduce costs through economies of scale and scope.

Another change that occurred in the mid–nineties was the introduction of a Multiple Component Pricing (MCP) system. The previous system only took into consideration the butterfat content of milk. The MCP system is based on the content of butterfat, protein (mainly casein) and other solids (lactose and minerals). This change is due to the decreasing value of butterfat in the market (CITT, 1998).

Before the 1995 WTO Agreement, Canada primarily used import quotas to control the imports of dairy products to maintain the supply management system. The WTO forced countries to convert import tariffs to Tariff Rate Quotas (TRQ), which allow a certain percent of past domestic consumption (Canada's "access commitment") to be imported at relatively low tariffs; and any quantity above that amount (that is, over the "access commitment") face high, usually prohibitive tariff rates (for cheese the over access commitment rate of duty is 267.3% —DFAIT, 2003). The TRQs are allocated to historical importers, mostly individual private firms (Canadian Dairy Industry Profile, 2002). These quotas can be rented and sold. In addition to the TRQs, there are import permits for processors to import dairy ingredients or products for further processing or re–export (Barichello, 1999).

Canada implemented a number of changes to the supply management structure because of the 1995 WTO negotiations. These changes include the elimination of both payments on dairy product exports financed by levies on milk producers and the industrial milk subsidy, organizing both pooling arrangements and quota exchanges and the introduction, modification and termination of several programs, like the Surplus Removal Program, the Optional Export Program and the Commercial Export Milk system (Food Bureau, 2003).

This research is important in the current trade environment. There have been many changes in the Canadian supply management system due to WTO negotiations. I examine the quality implications for these changes. Exporting countries are carefully analysing other countries' export and domestic support policies and can challenge them in the WTO if they cause trade distortions. The recent dispute about Canada's special milk classes is an example. The special milk classes provide competitive (low) prices for exports and further processing. New Zealand and the United States started the dispute and, in 1998, a WTO Dispute Panel was established. After several appeals, the panel concluded that the special classes constituted an export subsidy. In response, Canada had to change its policy.

2.2 Technical Background

Casein[8] is the main protein in milk and the main component of cheese. As an ingredient, it can be used in several products due to its various functional properties, including a higher yield in cheese and stability in yogurt and ice cream. It is also used in bakery and confectionary products. Milk protein concentrates (MPCs) are dairy blends without a strict definition and are not regulated in most countries (including Canada and the United States). This lack of definition and regulation enables exporting companies to label a wide range of products under this category, including mixes of skim milk, casein, caseinates and whey protein concentrates, or even mixes of cheese and other ingredients.

Some of these products can be categorized as extenders, which are mixes of functional ingredients such as dairy ingredients (skim milk powder, whey, whey protein concentrates, casein, caseinates, etc), starch, gums, stabilizers and enzymes; sometimes even flavours. These extenders are used in a variety of dairy products to increase yield. The most common use is in cheese. Extended cheese has been produced in many countries for several years. The type of extended cheese depends on each country's regulation and market (consumers' tastes and budget). Usually processed cheese includes extenders, not only to increase yield, but to provide stability and other functional properties. Cheese for further processing, such as mozzarella or pizza cheese, also may use extenders. Any cheese can be produced with extenders. The amount of extender used varies; it depends on the desired characteristics and price of the final product.

In general, 100 litres (lt) of milk produce 10 kilograms (kg) of cheese. To see the effect of extenders, in particular casein, if we add 1.5 kg of casein and 1.5 kg of fat to the 100 lt of milk, we obtain a 50% yield increase (Mangold, 2001). For yogurt, 1 lt of milk yields 1 lt of yogurt. The milk equivalents for ice cream are 3.8 lt of ice cream for 6.8 kg of milk, or 100 lt of milk yields 57.67 lt of ice cream (Potter and Hotchkiss, 1995).

Casein is used in yogurt and ice cream in fixed proportions given that it is a functional ingredient to provide stability. In cheese, casein is used as an extender to increase yield. Other

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[8] See Appendix III for a list of definitions.

than in processed cheese, where it provides stability, increased yield is the only functional property of casein in cheese. Unfortunately, there are no data available regarding production of processed cheese for the period studied. Data on the production of processed cheese are only recorded for Canada (not available by province) and ends in 1995 (Statistics Canada Table 303-0041).

The use of extenders is generally associated with a lower–quality product. Consumers are often unaware that they are being sold an "extended" product, which is inferior in quality when compared to traditionally manufactured products. Extenders are not harmful to human health, but the "extended" products may have different characteristics (especially flavour) than the traditional good. As an example, high–end (boutique) cheese and premium ice cream are exclusively manufactured using milk and cream (for ice cream). Generally, extenders are used in lower–priced products, like cheese for further processing and dairy spreads.

2.3 Industry Background

The two main classes of milk are the fluid market and the industrial market. The fluid market, which includes table milk and fresh cream, represents about 40% of the milk produced in Canada. Usually the price for this milk class is the highest. The industrial market consists of manufactured dairy products and accounts for the remaining 60% of total milk production (Dairy Market Review, 2001). The end use of cheese production is as follows: 60% retail, 25% food services and 15% intermediate ingredients (Canadian Dairy Industry Profile, 2002).

In 2001, 38.2% of milk production was processed under class 3 (cheese); 37.4% went to class 1 (fluid milk and cream); 4.3% was used for yogurt and ice cream; butter, milk powders and condensed milk accounted for 4.2% and all other dairy products cover the remaining 15.9% of total milk produced in Canada. Hard and semi–hard cheeses make up the majority (93.3%) of cheese production. Specialty cheeses account for nearly 25%, cheddar 35% and mozzarella 33.6%. Among the provinces, Quebec is the major cheese producer, representing almost half of the total production (Dairy Market Review, 2001). The market for specialty cheeses consists of more than 160 establishments, which are mainly small and artisanal (Canadian Dairy Industry Profile, 2002).

Casein, caseinates and MPCs are not subject to high import tariffs, making it less expensive for the processor to use them in the formulation relative to using only milk or other milk ingredients. The imports of casein (Figure 2.2) and caseinates, and whey and whey products have increased significantly since 1995, 178% and 75% respectively (Western Dairy Digest, 2003).

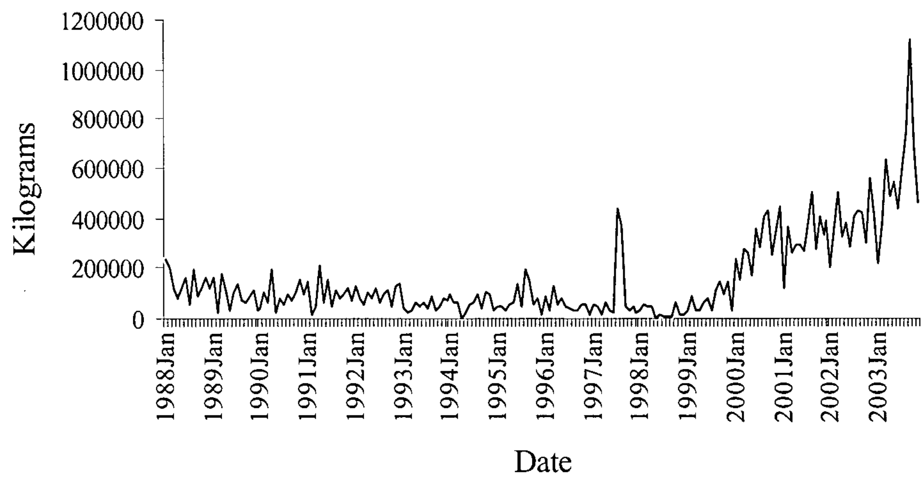

Figure 2.2: Casein Imports over Time

Casein is not produced in Canada anymore[9]. The last available information regarding casein production[10] is for 1977, but it was always a small percentage of casein imports into Canada. Domestic casein production in 1977 was equivalent to 14.42% of the imports in that year. Making the comparison with more recent data, domestic production of casein in 1977 is found to be only 0.108% of the 1988 imports. According to the Task Force on National Dairy Policy (1991), it is not profitable for Canadian processors to manufacture casein because of the high price of raw milk (the primary input in casein production) in the supply management system.

Along with the regulations, other changes have occurred in the Canadian cheese processing industry, which may explain the move to increase the use of extenders in cheese production. The structure of the Canadian dairy processing industry has undergone a significant rationalization process in the last decade. The shift to fewer and larger plants has been necessary to achieve the efficiency level and economies of scale required to remain competitive. Currently, the three major companies (Parmalat Canada, Agropur and Saputo Inc), who own 36% of the plants, process 70% of the milk produced in Canada (Canadian Dairy Industry Profile, 2002). Almost 27% of the plants operating in 1990 have been closed (Figure 2.3). Consolidation has also occurred at the retailing level, where the three major retailers account for more than 70% of the total grocery trade (Western Dairy Digest, 2001).

[9] Based on conversations with an industry representative and with an economist from Agriculture and Agri-Food Canada (Mario Casavant), March 2004.
[10] According to Statistics Canada Table 003-0048.

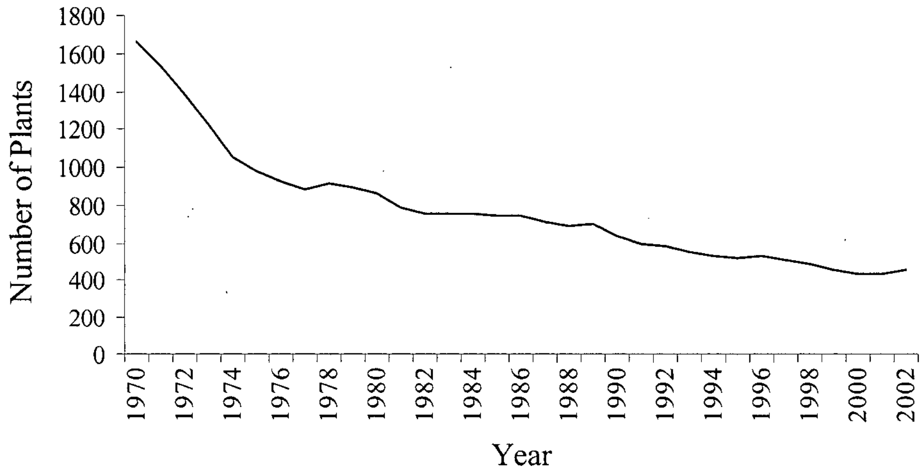

Figure 2.3: Number of Dairy Processing Plants over Time

The organization of the dairy processing industry is divided into three main structures. Producer–owned cooperatives produce 60% of the output. The remaining output is produced by prominent foreign–owned multinationals and Canadian–owned companies of varying size. Among these, the largest processors are multi–plant firms usually located in two or more provinces and with a diversity of products (Food Bureau, 2003).

Ontario and Quebec have the greatest number of dairy processing plants (130 and 166, respectively in 2002). In 1997, Quebec had 46.6% of the MSQ and Ontario 31.5%. Together the two provinces accounted for about 83% of the total value of industrial milk shipments. In terms of production, the percentages are similar: 85% of cheese production is in Quebec (50%) and Ontario (35%) (CDC, 2003).

According to a series of consultations between the Canadian Dairy Commission (CDC's Stakeholder Consultations, 2002) and groups involved in the dairy industry, a number of trends have emerged. Processors are having to become more competitive due to a decrease in market size. Consumers are moving away from dairy products and there is a reduction in the use of cheese. Major food–service companies are using less cheese in their products, or importing the final product at a lower cost.

Further processors have several options to try to reduce costs in the face of competitive pressures. Since the mid–nineties, further processors can buy their inputs at a lower price due to the implementation of the special milk classes, which allow producers to access milk at world prices. One problem with using this price is the uncertainty created by the volatility of the international milk price which is used to set the special classes' price. This uncertainty may prevent producers from using the special classes' prices. Thus, further processors are also trying to reduce costs by replacing dairy ingredients with cheaper imported ingredients.

3. THEORETICAL MODEL

In this chapter, I examine how the equilibrium quantity and quality of cheese and the number of processing plants are affected by the supply management system. In the context considered, quality is measured by the proportion of extended cheese in total production.

As noted above, the dairy processing industry in Canada is not perfectly competitive (Rude and Goddard, 1995). I assume monopolistic competition since the products are differentiated and there are fixed costs in cheese production. There are markets for both extended and non–extended cheese, and the two products are substitutes. The regular demand equations and inverse demand equations are linear functions of the two prices:

$$Q^n = a - P^n + bP^e \tag{3.1}$$

$$Q^e = c - P^e + dP^n \tag{3.2}$$

$$P^n = \frac{a + bc - Q^n + bQ^e}{1 - bd} \tag{3.3}$$

$$P^e = \frac{c + ad - Q^e + dQ^n}{1 - bd} \tag{3.4}$$

where Q^n and Q^e are the non–extended and extended market quantities; and P^n and P^e are the corresponding prices. Marginal cost (m^n and m^e) is lower for the extended cheese market, because milk substitutes are relatively less expensive ($m^e < m^n$). Fixed costs (F^n and F^e) are present in each market. Firms will set their quantity such that marginal revenue equals marginal cost in both markets.

The first order conditions for profit maximization are as follows:

$$\frac{a + bc - Q^n - bQ^e - \lambda^0 q^n - \lambda^1 bq^n}{1 - bd} - m^n = 0 \tag{3.5}$$

$$\frac{c + ad - Q^e - dQ^n - \lambda^0 q^e - \lambda^1 dq^e}{1 - bd} - m^e = 0 \tag{3.6}$$

where the lambdas are the conjectural variations[11]. When the value of lambda equals zero, the market is competitive, and when the value equals one, it is a monopoly.

$$dQ^n/dq^n = \lambda_0 \tag{3.7}$$

$$dQ^e/dq^e = \lambda_0 \tag{3.8}$$

$$dQ^e/dq^n = \lambda_1 \tag{3.9}$$

$$dQ^n/dq^e = \lambda_1 \tag{3.10}$$

The zero–entry conditions, where price equals average cost are:

$$\frac{a + bc - Q^n - bQ^e}{1 - bd} - m^n - \frac{F^n}{q^n} = 0 \tag{3.11}$$

$$\frac{c + ad - Q^e - dQ^n}{1 - bd} - m^e - \frac{F^e}{q^e} = 0 \tag{3.12}$$

[11] For simplicity, I am calling lambda the conjectural variation instead of one plus the conjectural variation, which is the correct name.

The total number of firms is represented by n, all of whom produce non–extended cheese, but only a fraction of these firms enter the extended market because firms differ with respect to the cost of entering this market (entry costs may vary because of different age of machinery). It is not profitable for a firm to produce only extended cheese, since some of the machinery is the same. Once a firm is producing extended cheese, it can start producing non–extended cheese to supply a different segment of the market, while the converse is not possible. This assumption is also based in conversations with industry representatives. Because of firm heterogeneity, the marginal firm earns zero profits and inframarginal firms earn positive profits. The firms entering the extended cheese market are assumed to have uniformly distributed fixed costs θ. The fixed cost of the marginal producer is denoted θ^*. K is the base fixed cost.

The equations for market supply of non–extended and extended cheese are given by:

$$F^e = \theta K \tag{3.13}$$

$$Q^n = \frac{n}{\bar{\theta} - \underline{\theta}} \int_{\underline{\theta}}^{\bar{\theta}} q^n d\theta = nq^n \tag{3.14}$$

$$Q^e = \frac{n}{\bar{\theta} - \underline{\theta}} \int_{\underline{\theta}}^{\theta^*} q^e d\theta = \left(\frac{\theta^* - \underline{\theta}}{\bar{\theta} - \underline{\theta}} \right) nq \tag{3.15}$$

The comparative statics[12] results (see Appendix IV), which show how equilibrium quantity of cheese produced is impacted by marginal cost and fixed cost in both markets, are described in Table 3.1. The effect of supply management is simulated by raising the marginal

[12] The analytical solution was obtained using the Symbolic Math Toolbox in MATLAB 6.1 (see Appendix IV).

cost for non–extended cheese because supply management makes the main input (milk) more expensive. This assumption is justified by several studies (Barichello and Stennes, 1994; Barichello, 1999; Richards, 1996; Richards and Jeffrey, 1997; Romain, 2001; etc.), as discussed in my review of the literature. The effect of extenders is modeled by setting comparatively low marginal costs for extended cheese production because, as noted above, extenders are less expensive than milk when used as a raw ingredient for cheese. I am primarily interested in the effect of supply management on the total quantity of extended and non–extended cheese and number of firms that operate in the industry.

Table 3.1: Comparative Statics Results

	dq^n	dq^e	dn	$d\theta^*$	dQ^n	dQ^e
dm^n	0	0	-	+	-	+
dm^e	0	0	+	-	+	-
dF^n	+	0	-	+	-	+
dK	0	+	+	-	+	-

As Table 3.1 shows, the effect of supply management is to decrease total quantity for non–extended cheese ($dQn/dm^n<0$) and increase total quantity for extended cheese ($dQ^e/dm^n>0$). These results are intuitive, since the two products are substitutes and supply management is raising the marginal cost for one of them. As well, there is a decrease in the total number of firms ($dn/dm^n<0$) and an increase in the fraction of firms that enter into the extended market ($d\theta^*/dm^n>0$). Specifically, a higher number of firms and firms with higher fixed costs will be able to adopt the technology and produce extended cheese. Consecutively, cheese prices will fall and the least competitive firms in the non–extended market will have to leave. These results together suggest that supply management lowers cheese quality.

The effect of introducing extenders (lower marginal cost for extended cheese) is to decrease the quantity of non–extended cheese ($dQ^n/dm^e>0$) and increase the quantity of extended cheese ($dQ^e/dm^e<0$). The number of total plants will decrease ($dn/dm^e>0$) and the fraction of firms entering the extended market will increase ($d\theta^*/dm^e<0$). If the cost of entry into the extended cheese market decreases (lower fixed costs for extended cheese), it implies a decrease in the total quantity of non–extended cheese ($dQ^n/dF^e>0$) and an increase in the total quantity of extended cheese ($dQ^e/dF^e<0$). The effect on the number of firms is to decrease the total number of firms ($dn/dF^e>0$) and increase the fraction of firms in the extended market ($d\theta^*/dF^e<0$). The results for the changes in total quantity for extended and non–extended cheese are intuitive by the same logic as above, since the products are substitutes. Both effects, lower marginal and fixed costs for extended cheese imply a decrease in the total number of firms and an increase in the fraction of firms to enter the extended market. This means that more firms will enter the extended market, driving down the cheese price and thus, decreasing the total number of plants.

The effects of supply management, because of increased marginal costs, are to lower cheese quality, to decrease the total number of firms and to induce more firms and firms with higher fixed costs to produce extended cheese. Since more firms will be producing extended cheese, cheese price will fall, and some of the firms in the non–extended market will have to leave. Firms have two options to decrease costs: economies of scale and scope and the use of extenders.

4. EMPIRICAL MODEL

Using the results obtained in the previous chapter, I wanted to estimate the actual change in quality, quantity and number of firms as a function of the marginal and fixed costs. I am mainly interested in the quality changes. The first problem I encountered was the lack of data regarding extended (vs. non–extended) cheese and several other variables of interest. Because it is not possible to differentiate between the two types of cheese in the dataset, it is necessary to estimate the demand for extenders as a function of the price of all inputs, price of all outputs and number of firms. But there are also some limitations regarding extenders. Given that extenders can be mixes of different ingredients, they are categorized into broad definitions, making it impossible to get information about production, utilization, imports and exports.

To solve this, I decided to use casein as a proxy for extenders. As mentioned in the Technical Background part of chapter 2, casein is considered an extender on its own (since it increases yield in cheese), and it is also included in cheese extenders that contain other ingredients. I estimate the demand for casein as a function of outputs, marginal costs and number of plants. With these results, I determine the effect of these high levels of protection on cheese quality.

As noted above, Canada did not produce casein in the period studied (1993 to 2002). The casein available for domestic consumption is all imported[13].

[13] There is some re-exportation of casein, but it is supposed to be imported under a different category (imports for re-export).

Due to data restrictions, it is not possible to directly estimate the demand for casein. There are many products that use casein and not only in the dairy industry. In addition, there are no data available regarding inputs. Instead, I estimate the derived demand for casein[14] as a function of the reduced form demand for the outputs (cheddar, specialty cheese, ice cream and yogurt), the marginal costs and the number of plants. The marginal costs are the costs for the main inputs, that is, milk price, metal index (because is the major component for machinery) and wages (labour costs).

The overview of the econometric approach is as follows[15]:

1. Estimate the derived demand for casein as a function of outputs (cheddar cheese, specialty cheese, yogurt and ice cream), marginal costs (milk price, metal index and wages) and the number of plants (equation 4.1).
2. Instrument the endogenous variables with suitable variables (equations 4.2 to 4.6).
3. Test and correct for heteroskedasticity and autocorrelation.

The derived demand is obtained from the reduced form demand equations for the dairy products that use casein, that is, cheddar, specialty cheese, yogurt and ice cream, taking into account the marginal costs (the price of milk, metal index and wage) and the number of plants. This yields the estimation equation 4.1 in which casein is a function of the outputs (cheese, ice cream and yogurt quantities instrumented with their own reduced form demand equations 4.2 to 4.5), the marginal costs (milk price, metal index and wage) and the number of plants. A lag for casein imports, the casein price (instrumented with equation 4.6), a time trend, a dummy variable for the years 2000 to 2002 and a dummy variable for the years post–GATT are also used in the estimation equation 4.1.

[14] See Appendix V for the data description.

The data for number of plants are annual and is left constant through the year. The methodology for the Annual Survey of Manufactures (ASM) changed in 2000 when the data universe was expanded to include all manufacturing units, instead of only recording data from manufacturing businesses over $30,000 in sales of manufactured goods and with employees. This change represented an increase of around 100% in the number of plants from 1999 to 2000. To obtain a consistent dataset, I transformed the number of plants from 1993 to 1999 to the new methodology based on the annual change from the old methodology. This transformation was done assuming the trend in the number of plants was the same for plants of all sizes. The complete information on the manipulation required to obtain consistent data for number of plants is included in Appendix V.

The supply of the final product (cheese, yogurt and ice cream) could be affected by the quantity of an input (like casein), that is the reason to instrument[16] the quantities of cheddar, specialty cheese, yogurt and ice cream, using variables that affect their demand (unemployment, population, income, CPI for all products, cheese and dairy products, IPI for ice cream, one lag, an annual time trend and an annual time trend squared). The casein price was instrumented because of concerns of endogeneity and variables that affect the supply price of casein imports were used as instruments: the U.S. industrial milk price, the U.S. energy index, the U.S. wage and the Canada–U.S. exchange rate. The casein price used was computed by dividing casein import value by casein import quantity. In the cases where there are no casein imports (15 observations for Quebec), the average of the adjacent observations was used.

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[15] See Appendix VI for the code used and Appendix VII for the heteroskedasticity correction.

[16] The Hausman Test rejects the null of non–endogeneity for the model.

In the supply side, technology has changed in the last years; in the demand side, there have been changes in tastes, the annual time trend is capturing these effects. The lags are included to correct for autocorrelation. The dummy variable for the years post–GATT captures the changes in regulations due to the GATT, like the elimination of the industrial milk subsidy and the change from import quotas to import tariffs. The dummy variable for the years 2000 to 2002 captures the elimination of the export program.

$$\begin{aligned}\text{Casein}_{it} = {} & \beta_0 + \beta_1\text{Casein}_{it-1} + \beta_2\text{Casein Price}_{it} + \beta_3\text{Cheddar}_{it} + \beta_4\text{SpecialtyCheese}_{it} \\ & + \beta_5\text{Yogurt}_{it} + \beta_6\text{IceCream}_{it} + \beta_7\text{Milk Price}_{it} + \beta_8\text{MetalIndex}_{it} + \beta_9\text{Wage}_{it} \\ & + \beta_{10}\text{Plants}_{it} + \beta_{11}\text{Time}_{it} + \beta_{12}\text{Y00} - 02_{it} + \beta_{13}\text{GATT}_{it} + \varepsilon_0\end{aligned} \tag{4.1}$$

where:

- Subscript i refers to the province (Ontario or Quebec) and t to the date (monthly from January 1993 to December 2002).
- Casein is the quantity of casein imported and Casein_{t-1} is the lag for casein imports in period one.
- Casein Price is the price for casein calculated as the value of casein imports divided by the quantity of casein imports and instrumented with the U.S. industrial milk price, the U.S. energy index, the U.S. wage and the Canada–U.S. exchange rate.
- Cheddar, Specialty Cheese, Yogurt and Ice Cream are the respective quantities produced, instrumented with the reduced form demand equations for each product in equation 4.1.
- Milk Price is the weighted average for all the milk classes except class 1 (fluid consumption).
- Metal Index is the index price for metal (primary steel products).

- Wage is the fixed weighted index of average hourly earnings for all employees for non–durable industries.
- Plants is the number of dairy processing plants.
- Time is the annual time trend.
- Y00-02 is a dummy variable for the years 2000 to 2002.
- GATT is a dummy variable for the years post–GATT (1995-2002).

This estimation is used to test the following hypotheses:

1. Casein imports are positively correlated with the weighted milk price. The results of the theoretical model predict β_7 to be positive.
2. Casein imports are positively correlated with cheese production. Thus, the coefficients β_3 and β_4 are expected to be positive.
3. Casein imports are negatively correlated with number of firms. The coefficient β_{10} is expected to be negative because of the consolidation trend discussed in the Industry Background section. There is a pressure for the firms to become competitive. Some options they have to reduce costs are through economies of scale and scope and to produce extended cheese.

The reduced form demand equations are:

$$\begin{aligned} \text{Cheddar}_{it} = {} & \alpha_0 + \alpha_1 \text{Cheddar}_{it-1} + \alpha_2 \text{Unemployment}_{it} + \alpha_3 \text{Population}_{it} \\ & + \alpha_4 \text{Income}_{it} + \alpha_5 \text{CPI}_{it} + \alpha_6 \text{CPI\_Cheese}_{it} + \alpha_7 \text{CPI\_DP}_{it} \\ & + \alpha_8 \text{IPI\_IC}_{it} + \alpha_9 \text{Time}_{it} + \alpha_{10} \text{Time}^2{}_{it} + \varepsilon_1 \end{aligned} \tag{4.2}$$

$$\begin{aligned} \text{SpecialtyCheese}_{it} = {} & \gamma_0 + \gamma_1 \text{SpecialtyCheese}_{it-1} + \gamma_2 \text{Unemployment}_{it} \\ & + \gamma_3 \text{Population}_{it} + \gamma_4 \text{Income}_{it} + \gamma_5 \text{CPI}_{it} + \gamma_6 \text{CPI\_Cheese}_{it} \\ & + \gamma_7 \text{CPI\_DP}_{it} + \gamma_8 \text{IPI\_IC}_{it} + \gamma_9 \text{Time}_{it} + \gamma_{10} \text{Time}^2{}_{it} + \varepsilon_2 \end{aligned} \tag{4.3}$$

$$\begin{aligned} Yogurt_{it} = & \delta_0 + \delta_1 Yogurt_{it-1} + \delta_2 Unemployment_{it} + \delta_3 Population_{it} \\ & + \delta_4 Income_{it} + \delta_5 CPI_{it} + \delta_6 CPI\_Cheese_{it} + \delta_7 CPI\_DP_{it} \\ & + \delta_8 IPI\_IC_{it} + \delta_9 Time_{it} + \delta_{10} Time^2{}_{it} + \varepsilon_3 \end{aligned} \tag{4.4}$$

$$\begin{aligned} IceCream_{it} = & \varphi_0 + \varphi_1 IceCream_{it-1} + \varphi_2 Unemployment_{it} + \varphi_3 Population_{it} \\ & + \varphi_4 Income_{it} + \varphi_5 CPI_{it} + \varphi_6 CPI\_Cheese_{it} + \varphi_7 CPI\_DP_{it} \\ & + \varphi_8 IPI\_IC_{it} + \varphi_9 Time_{it} + \varphi_{10} Time^2{}_{it} + \varepsilon_4 \end{aligned} \tag{4.5}$$

where I included a lagged variable for the production quantities. Unemployment is the number of unemployed individuals; Population is quarterly by province; Income is the average market income, for all family units; CPI is the Consumer Price Index, 2001 basket content, all items; CPI_Cheese is the Consumer Price Index, 2001 basket content, cheese; CPI_DP is the Consumer Price Index, 2001 basket content, dairy products; IPI_IC is the Industrial Price Index, ice cream and ice milk products; Time is the time trend; and $Time^2$ is the time trend squared. The units for these products were scaled according to the yield mentioned in the Technical Background section so they would correspond to the yield from one hl of milk. Later, they were scaled again to obtain homogeneous results in terms of magnitude of the coefficients. Specifically, the units used to run the regressions are: cheese in 100,000 kg, yogurt in 1,000,000 kg and ice cream in 576,700 lt.

The equation used to instrument the casein price is the following:

$$\begin{aligned} Casein\,Price = & \eta_0 + \eta_1 USMilk\,Price + \eta_2 USEnergyIndex \\ & + \eta_3 USWage + \eta_4 ExchangeRate + \varepsilon_5 \end{aligned} \tag{4.6}$$

where US Milk Price is the U.S. price for industrial milk, converted to U.S. dollars/hl. US Energy Index is the industrial electric power index for the United States, US Wage is the average hourly earnings of production workers for manufacturing in the United States. Finally, Exchange Rate is the Canada –U.S. exchange rate.

The only two provinces used for the estimation are Ontario and Quebec. Technology is assumed to be homogeneous across provinces[17]. The time frame considered is from 1993 to 2002, most of the data used were obtained through Statistics Canada and are monthly, by province. The production data include exports. The weighted average price takes into consideration all prices and volumes, including the lower (competitive) prices for the special classes. The special classes are cheese for further processing (mainly mozzarella and pizza cheese, some cheddar), other dairy products for further processing, dairy products for confectionery and planned exports.

The above system of equations was estimated using three–stage least squares in STATA[18]. This command allows estimating a system of structural equations (equations 4.1 to 4.6), where the left–hand side variables in equations 4.2 to 4.6 are explanatory variables in equation 4.1. In this way, I instrument the production quantities used in the main estimation equation (equation 4.1) with their own demand equations (equations 4.2 to 4.5) and the casein price with the variables described in equation 4.6. All other variables are treated as exogenous to the system and they are used as instruments for the endogenous variables. Three–stage least squares also assumes that the error terms may be correlated across the equations. The following table presents the summary statistics of the variables, excluding the time trend and the dummy variables.

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[17] Based on a conversation with Michel Britten, Research Scientist Food Safety and Quality, Agriculture and Agri-Food Canada, March 2004.

Table 4.1: Summary Statistics (continued in next page)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Casein Imports, 10,000 kg	240	6.49	8.17	0.00	41.90
Casein Price, dollars/kg	240	6.55	1.18	3.09	10.23
Cheddar, 100,000 kg	240	41.46	11.94	18.05	76.45
Specialty Cheese, 100,000 kg	240	69.98	26.17	34.61	144.62
Yogurt, 1,000,000 kg	240	4.19	1.55	1.55	8.88
Ice Cream, 576,700 lt	240	14.85	10.47	0.28	40.18
Milk Price, dollars/hl	240	45.71	4.24	33.34	57.73
Metal, index (1997=100)	240	96.43	5.85	79.30	103.00
Wage, index (1996=100)	240	103.87	6.96	92.30	116.00
Plants, number	240	140.30	31.49	103.00	185.00
Unemployment, 100,000 individuals	240	4.26	0.82	2.86	6.67

[18] The code used is included in Appendix VI.

Table 4.1 Summary Statistics (continued)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Population, 100,000 individuals	240	93.06	20.46	71.36	121.53
Income, 100 dollars	240	40.21	6.50	31.33	51.08
CPI, index (1992=100)	240	107.94	5.79	99.30	121.80
CPI Cheese, index (1992=100)	240	109.58	5.50	99.70	122.60
CPI Dairy Products, index (1992=100)	240	107.06	7.04	92.20	122.40
IPI Ice Cream, index (1997=100)	240	97.63	3.88	89.10	106.10
U.S. Milk Price, U.S. dollars/hl	240	27.99	3.66	21.63	39.61
U.S. Wage, U.S. dollars/hour	240	12.65	1.19	10.86	14.84
U.S. Energy, index (Jan 1998=100)	240	132.45	5.84	125.20	149.50
Exchange Rate, CAD/USD	240	1.44	0.09	1.25	1.60

5. RESULTS

The main results of the regression of casein as a function of dairy product quantity and other inputs are displayed in Table 5.1. The three columns correspond to the different specifications of the model. The model represented in column I includes yearly dummies in all equations and a dummy variable for the months April to August and December in the cheddar and yogurt equations, April to August in the specialty cheese equation and March to August in the ice cream equation, when sales for each product were elevated.

Column II is the simple model presented in chapter 4. There is some evidence suggesting that the residuals are heteroskedastic and autocorrelated. Heteroskedasticity problems were addressed using a modified version of the White method to correct the variance–covariance matrix to obtain robust standard errors (see Appendix VII). To correct for autocorrelation, several modifications to the model were used, where the specification in the first column resulted the more appropriated one. Finally, column III represents the Tobit estimates, since some values of casein imports and casein price are zero (as mentioned in Appendix V).

The results obtained in the three columns are quite similar[19], except for the GATT dummy and the number of plants in the Tobit model, but both coefficients are not significant. For the analysis and simulation of the results only the coefficients in column I are used, since they are robust to heteroskedasticity and autocorrelation.

[19] Even though the standard errors are not correct due to heteroskedasticity and autocorrelation, the coefficients on columns II and III are unbiased. Thus, it is valid to compare them.

Table 5.1: Estimation Results

Dependent Variable: Casein Imports, 10,000 kg			
Variable	**I**	**II**	**III**
Lagged Casein Imports, 10,000 kg	0.225[a]	0.260[b]	0.242[a]
	(0.063)	(0.103)	(0.065)
Casein Price, Dollars/kg	-4.589[a]	-4.734[a]	-2.967[c]
	(1.025)	(0.926)	(1.732)
Cheddar, 100,000 kg	-0.281[b]	-0.175	-0.319[b]
	(0.124)	(0.154)	(0.132)
Specialty Cheese, 100,000 kg	0.295[a]	0.230[a]	0.215[a]
	(0.067)	(0.077)	(0.059)
Yogurt, 1,000,000 kg	-3.517[a]	-3.130[b]	-2.332[b]
	(1.317)	(1.378)	(1.055)
Ice Cream, 576,700 lt	0.223[a]	0.179[b]	0.178[b]
	(0.080)	(0.085)	(0.084)
Milk Price, dollars/hl	0.217[b]	0.257[a]	0.214[b]
	(0.111)	(0.097)	(0.101)
Metal, index (1997=100)	-0.567[b]	-0.418[b]	-0.170
	(0.254)	(0.187)	(0.135)
Wage, index (1996=100)	-0.383	-0.568[b]	-0.465[c]
	(0.297)	(0.277)	(0.281)
Plants, number	0.014	0.014	-0.016
	(0.034)	(0.038)	(0.024)
Yearly time trend	-	2.402[a]	2.426[b]
	-	(0.854)	(0.981)
Y00-02, 1 from 2000 to 2002	-	11.804[a]	10.116[a]
	-	(2.855)	(1.995)
GATT, 1 after 1994	-	6.297[c]	-0.626
	-	(3.531)	(2.253)
R^2	0.256	0.243	0.131
Number of Observations	238	238	238

Note: Standard errors are reported in parenthesis with a, b and c denoting significance at the 1%, 5% and 10% levels, respectively.

The casein equation fits relatively poorly, with an R^2 equal to 0.256. This poor fit can be explained by the fact that casein is used in a variety of products, some of which I was not able to include in the regression. In the food industry casein is also used in bakery and confectionary products. But casein is also used in other manufacturing industries. Unfortunately there is not information regarding other uses for casein. The R^2 statistics for the demand equations are higher (see Tables 5.3 to 5.6).

In accordance with my hypotheses, I test whether casein imports are positively correlated with the weighted milk price (β_7 is positive) and with the production of cheese (β_3 and β_4 are positive); and negatively correlated with number of firms (β_{10} is negative). The coefficients on milk price and specialty cheese are positive and significant (specialty cheese at the 1% level and milk price at the 5% level), whereas the coefficient on cheddar is negative and significant at the 5% level. The milk price is the average weighted price taking into account the lower (competitive) prices for the special classes. If the milk price rises one dollar per hectolitre, it increases the casein imports by 2,170 kg (3.34% of the average monthly casein imports), *ceteris paribus*. The elasticity of substitution between casein and milk is 1.53.

To obtain 10 extra kg of specialty cheese, 0.295 kg more casein is required. If, according to the example described in Technical Background, adding 1.5 kg of casein to one hl of milk yields 5 kg extra of cheese, then an equivalent of 9.8% of the production of specialty cheeses is extended. This result should not be interpreted literally, rather it gives an idea of the magnitude of the percentage of extended cheese if all processors in the extended market were using 1.5 kg of casein per one hl of milk. The coefficient on cheddar is negative, suggesting that cheddar is manufactured in the traditional way. The positive sign on the coefficient on specialty cheese is driven by mozzarella cheese, which makes up the majority of this class. Mozzarella cheese is mainly used in pizza. As discussed in previous chapters, there is a trend to decrease costs for cheese for further processing, even with the lower price assigned to the milk used for this class.

Next, I estimate the amount of milk that is being displaced by casein[20]. If milk price increases one dollar/hl, the 2,170 kg increase per month in casein imports will displace 722.65 hl of milk per month. Thus, a one dollar increase in the price of milk would suggest that there is a spillover effect of supply management that increases input substitution away from domestic milk, which decreases the revenue created by supply management by 37,701 dollars per month for Ontario and 40,230 dollars per month for Quebec, per month (using the weighted price for milk of December 2002); or 33,033 dollars per month using the average weighted price for the period studied (1993 to 2002).

The coefficient on yogurt is negative and the one on ice cream is positive, both are significant at the 1% level. These coefficients are not as meaningful as those on cheddar and specialty cheese because the functional properties of casein in yogurt and ice cream are different than in cheese. The results, however, imply that a 100 kg increase in yogurt production decreases casein imports 3.52 kg, and an increase of 57.67 lt of ice cream increases casein imports 0.22 kg.

The coefficient on the lagged casein imports is positive and significant at the 1% level, as expected, because demand is usually based on past consumption. The casein price

[20] To estimate the amount of milk displaced by casein, I took the formula to extend cheese (1.5 kg of casein yield 5 extra kg of cheese) and used the coefficient on milk price to calculate the corresponding amount of extra cheese being produced. Then, I multiplied that number times the yield for cheese (10%) to obtain the quantity of milk.

coefficient also has the expected negative sign and it is significant at the 1% level. This result suggests a negative own price effect for casein, giving an own price elasticity of -4.63. The effect of a one dollar increase in the price of casein, for example due to the implementation of a tariff, is to decrease casein imports by 45,890 kg per month (70.7% of the average monthly casein imports). This translates into 15,296 hl per month more milk being used in cheese manufacturing, and an average increase in farmers' revenue of 699,175 dollars per month. The value of casein imports for Quebec in December 2002 is 1,137,695 dollars. Adding a 50% *ad valorem* tax on casein imports increases the amount of money paid to 1,706,542.5 dollars. Using the quantity imported for this period, the casein price before the tariff is 6.34 dollars/kg and after the tariff is 9.51 dollars/kg. The increase in price decreases casein imports by 145,514 kg per month (224% of the average monthly casein imports), translating into 48,505 hl more milk per month being used in cheese processing and an average increase in farmers' revenue of 2,217,141 dollars per month. To drive casein imports down to zero, a 22% *ad valorem* tariff is needed. These results provide justification for Canadian dairy farmers' concern about implementing tariffs on casein and similar products.

The coefficient on the number of plants is positive, although not significant. My theoretical model predicted this coefficient to be negative. The empirical result may be driven by the manipulation needed to obtain consistent data as discussed in Appendix V. However, some authors claim through theoretical models that, if the quantity is lower and the price is higher than socially optimal, a monopolist might choose the same level of quality for a good as the social optimum (Acharyya, 1998; Beath and Katsoulacos, 1991 and Lambertini, 1998). This is consistent with my findings. Removing one plant from the market is associated with a 140 kg (0.21% of the average monthly casein imports) decrease in casein imports.

Variable costs are negative as expected. Metal is significant at the 5% level, whereas wage is not statistically significant. An increase of one in the metal index, decreases casein imports by 5,674 kg (8.7% of the average monthly casein imports). For wage, the decrease is lower: 3,830 kg (5.9% of the average monthly casein imports).

The results suggest that casein is highly positively affected by changes in the price of milk. A one dollar increase in the price of milk causes around 723 hl of milk to be displaced per month, which means that there is a spillover effect of supply management that increases input substitution away from domestic milk, which decreases the revenue created by supply management by approximately 33,000 dollars per month. This correlation is also observed between casein and the output quantities specialty cheese and ice cream. As mentioned above, the regression results suggest an equivalent of 9.8% of the production of specialty cheese is extended. The results for cheddar suggest that this kind of cheese is manufactured in the traditional way. For yogurt, the coefficient is negative. This result can be explained because casein may be making other products easier and/or less expensive to produce relative to yogurt and, therefore, a substitution away from yogurt is observed. The coefficient on yogurt may also be reflecting some other trends, like demand for healthier food. According to the Food Bureau (2003), "growth in yogurt demand since the late–eighties has been driven by demand for more health–oriented food".

I conclude that supply management, by increasing the price of milk, is negatively affecting cheese quality. On the other hand, the decreasing number of plants has a positive effect (although not significant) on quality (lowering the imports of casein). I cannot make any assumptions concerning the driving forces of this decrease, or what would happen to the number of plants without supply management. Besides, consolidation is a trend observed worldwide in many industries.

There are also other factors negatively affecting cheese quality, like the GATT, changes in the supply management system and technology. These changes are captured in the yearly dummies (Figure 5.1). There is some evidence of an increasing step function[21]. The first occurs at the same time as the implementation of the GATT in 1995 and the second one coincides roughly with elimination of the export program (August 2000). The elimination of the industrial milk subsidy started shortly after the GATT and was completed by February 2002.

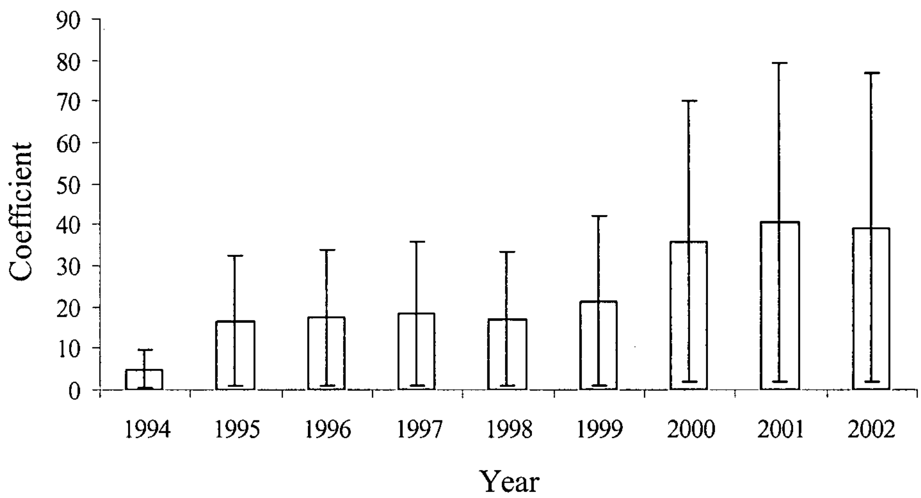


Figure 5.1: Coefficients on the Year Dummies in the Casein Equation

With the export program, processors had access to less expensive milk. Once the program was eliminated, they had to keep costs low to be able to continue to export. One option is to switch technology and produce extended cheese. Since 1993, exports have been

[21] I tested for aggregation of the year dummies. The results suggested that the coefficients for the years 1995 to 1999 and 2001 to 2002 were statistically equal. Once incorporated into the model as dummy variables for 1995-

steadily increasing. Even after the elimination of the export program, dairy exports have continued to increase. Decreases were only experienced in 1999 and to a larger degree in 2000. Table 5.2 summarizes the average exports per year for some selected dairy products (Dairy Trade Bulletin – Dairy Year 2001-2002).

Table 5.2 Average Exports per year for Selected Dairy Products

Product	Average per year (tonnes) 1998-2000	2000-2002
Cheese	25,399	17,412
Dairy Spreads	6,381	14,370
Products consisting of Natural Milk constituents	8,439	13,102
Total Dairy Products	159,407	180,997

Exports of cheese have been decreasing, but exports of dairy spreads and products made from milk ingredients have been increasing substantially. These products use more casein. Unfortunately, due to broad classification and lack of data regarding production, these products cannot be included in the analysis. However, export numbers suggest that production of these products has been increasing, which accounts for the significant coefficient on the weighted price for milk. These findings are also reflected in the result for the dummy variables for the years after the elimination of the export subsidy, 2000, 2001 and 2002 (Figure 5.1). Technological change may also have contributed to these findings.

The effect of supply management can be measured by comparing the milk price difference between Canada and the United States. The U.S. price for industrial milk in

1999 and 2001-2002, the model presented heteroskedasticity and autocorrelation problems, but the other coefficients were quite similar.

December 2002 was 24.13 USD/hl. Using the exchange rate for December 2002, 1.56 CAD/USD, the price is 37.64 dollars/hl. The weighted milk price for December 2002 is 52.17 dollars/hl for Ontario and 55.67 dollars/hl for Quebec. The difference is 14.52 dollars/hl for Ontario and 18.03 dollars/hl for Quebec. The average difference in price for both provinces is 16.28 dollars/hl. The higher price for industrial milk in Canada than in the United States increased casein imports by 35,294 kg (54.4% of the average monthly casein imports). This means that in December 2002, 11,765 hl of milk were displaced, causing a spillover effect that decreases farmers' revenue by 634,358 dollars (using the average weighted milk price for Ontario and Quebec in December 2002).

In December 2002, the total volume of milk produced in Quebec was 2,222,428.2 hl, generating 36,181,131 dollars in extra revenue for farmers due to supply management. At the same time, supply management also caused a spillover effect that decreased farmers' revenue by 654,946 dollars. The spillover effect is 1.81% of the extra revenue, which is a considerable amount for Canadian farmers.

For the next part of the simulation, I use the coefficients on the dummy variable for the years 2000 to 2002 and on the dummy variable for the years post–GATT from column II (Table 5.1). This specification was corrected for heteroskedasticity, but the residuals are still autocorrelated. Even though the standard errors are not correct, the coefficients are unbiased and can be used for simulation purposes. I examine the different effects of supply management (as captured by the difference in price between Canada and the United States), the elimination of the export program (as captured in the dummy for the years 2000 to 2002) and the elimination of the industrial milk subsidy (as captured by the dummy for the years post–GATT) on the imports of casein by comparing the extra quantity of casein imported because of these three factors.

The dummy variable for the years 2000 to 2002 is positive. This result is interesting since it coincides with the elimination of the export program in August 2000. It can be considered as an approximate measure of the average difference in kilograms of casein with and without the export program. Thus, imports of casein greatly increased after the elimination of the export program. The dummy variable for the years post–GATT is positive. This result was expected given the changes in regulation, like the elimination of the industrial milk subsidy, occurred after the GATT.

The quantity of casein imported after the GATT is 62,970 kg (97% of the average monthly casein imports) and after the year 2000 it increased to 118,040 kg (182% of the average monthly casein imports). These two dates mark changes in the supply management system as well as technological changes. After the year 2000, 39,348 hl of milk were displaced, producing a decrease in farmers' revenue of 1,798,603 dollars due to the spillover effect. After the GATT, 20,989 hl of milk were displaced and the spillover effect decreased farmers' revenue by 959,386 dollars. As mentioned before, the effect of supply management as captured by the difference in milk price between Canada and the United States increased casein imports in December 2002, by 35,294 kg (54.4% of the average monthly casein imports), displacing 11,765 hl of milk and causing a spillover effect that decreases farmers' revenue by 634,358 dollars.

Comparing the three effects, one can see that the elimination of the export program, as captured by the dummy for the years 2000 to 2002, caused the greatest decrease in farmers' revenue due to the spillover effect, followed by the elimination of the industrial milk subsidy (dummy post–GATT) and then the effect of supply management. The effect of supply management caused around 35% of the revenue loss to farmers due to the elimination of the export program (dummy for the years 2000 to 2002) and 66% of the revenue loss to farmers due to the elimination of the industrial milk subsidy (dummy post–GATT). That said, the end of the export program and the industrial milk subsidy may only have precipitated faster technical change that may well have occurred anyway, especially in the last two years. Therefore, this result should not be interpreted literally but it gives an idea of the impact Canadian regulations have had on the increase in the imports of casein.

The results for the demand equations are displayed in the following tables and figures (Tables 5.3 to 5.6 and Figures 5.2 to 5.5). There is a good fit for all the equations. The coefficient on the lagged variable for all demand equations is positive, significant at the 1% level for specialty cheese, yogurt and ice cream, and significant at the 5% for cheddar. This is an intuitive result, since production and demand are usually based on past consumption. Somewhat counter–intuitively, the coefficient on unemployment is positive for cheddar (not significant) and ice cream (significant at the 5% level); negative for specialty cheese (significant at the 1% level) and yogurt (not significant). For population, the coefficient is negative for all products. The coefficient on income is positive for all products, but only significant for ice cream (1% level). These results suggest that there is a positive income effect on cheddar, specialty cheese, yogurt and ice cream. This was expected for yogurt, since it is perceived by consumers to be healthier or nutritionally beneficial. Also, mozzarella is included in specialty cheese and its main use is in pizza and prepared meals, which have been increasing in popularity in the last years.

The coefficient on CPI is positive for cheddar, specialty cheese and ice cream (significant at the 5% level), and negative and significant at the 1% level for yogurt. This implies that as inflation increases, people demand less yogurt. The CPI for dairy products is assumed to be capturing the overall trend in dairy products. The coefficient on this variable is negative for cheddar (significant at the 1% level) and ice cream, and positive for specialty cheese (significant at the 1% level) and yogurt. The CPI for cheese and the IPI for ice cream reflect the own price and cross price effects of each product. For cheddar, there is a negative own price effect and positive cross price effect with ice cream, both of them are not significant. For specialty cheese, both effects are negative and not significant. For yogurt, the cross price effect captured by the CPI for cheese is positive, but the cross price effect captured by the IPI for ice cream is negative, both of them are significant at the 1% level. Ice cream presents a negative cross price (cheese) effect and a positive own price effect, both of them not significant.

The yearly dummies for the cheddar and yogurt equations present a rapidly increasing trend. For cheddar, it starts in 1994 with 359 tonnes, and increases to 3,065 tonnes in the tenth year (2002). Yogurt starts with the negative amount of 93 tonnes in 1994, and increases to 3,709 tonnes in the tenth year. The yearly dummies for specialty cheese and ice cream present a rapidly decreasing trend, although it seems that in the last year the trend may start to be increasing. Specialty cheese starts with a negative amount of 63 tonnes in 1994 and rapidly decreases to 2,578 tonnes in the tenth year. There is only one positive amount for specialty cheese, in 1997 there is an increase of 277 tonnes. For ice cream, it starts with positive amounts, 203 tonnes in 1994, increases to 550 tonnes in 1995, and starts decreasing in 1996 (281 tonnes), until it reaches the negative amount of 4,396 tonnes in 2002. As mentioned before, theses trends can be due to changes in regulation, consumer trends or technology. Unfortunately, it is not possible to distinguish clearly between the effects.

The results for the casein equation are displayed in Table 5.7 and Figure 5.6. The coefficients have the expected signs, positive for U.S. Milk Price and Exchange Rate (CAD/USD) and negative for U.S. Wage and U.S. Energy. As the milk price increases, there will be a greater demand for casein thereby increasing casein price. The coefficient on exchange rate suggests that if the Canadian dollar depreciates compared to the U.S. dollar, casein price will increase. The coefficients on wage and energy capture changes in marginal costs for cheese. Cheese production will decrease with an increase in the marginal cost and thus, casein use and price will decrease as well. The coefficients on the yearly dummies capture technological changes and consumer trends. They present an alternated increasing and decreasing trend.

To test for robustness, several alternatives to the model were tried. Some of the experiments include adding a second lag for all products, lags for metal, running the first differences equations, using fixed effects and eliminating the outliers. The results obtained from these experiments were either very similar to the original ones, or the coefficient on the new variable was not significant. Heteroskedasticity problems were addressed using a modified version of the White method to correct the variance–covariance matrix to obtain robust standard errors (see Appendix VII). In the final specification, yearly dummies and some month dummies were added to correct for autocorrelation. The addition of these variables also corrected the heteroskedasticity problem. Thus, the results are robust.

Table 5.3: Reduced Form Demand for Cheddar (equation 4.2)

Dependent Variable: Cheddar, 100,000 kg		
Variable	**Coefficient**	**Standard Error**
Lagged Cheddar, 100,000 kg	0.147[b]	0.062
Unemployment, 100,000 individuals	0.487	1.013
Population, 100,000 individuals	-0.606[c]	0.340
Income, 100 dollars	0.385	1.147
CPI, index (1992=100)	0.212	0.460
CPI Cheese, index (1992=100)	-0.297	0.322
CPI Dairy Products, index (1992=100)	-1.146[a]	0.318
IPI Ice Cream, index (1997=100)	0.124	0.204
R^2	0.806	
Number of Observations	238	

Note: a, b and c denotes significance at the 1%, 5% and 10% levels, respectively.

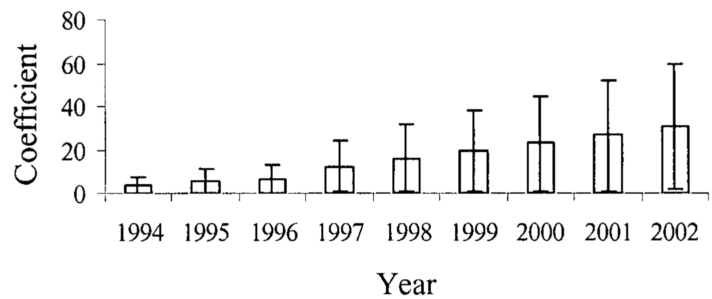


Figure 5.2: Coefficients on the Year Dummies in the Cheddar Equation

Table 5.4: Reduced Form Demand for Specialty Cheese (equation 4.3)

Dependent Variable: Specialty Cheese, 100,000 kg		
Variable	**Coefficient**	**Standard Error**
Lagged Specialty Cheese, 100,000 kg	0.415[a]	0.056
Unemployment, 100,000 individuals	-3.182[a]	1.233
Population, 100,000 individuals	-1.245[a]	0.417
Income, 100 dollars	2.052	1.403
CPI, index (1992=100)	0.784	0.561
CPI Cheese, index (1992=100)	-0.412	0.401
CPI Dairy Products, index (1992=100)	1.103[a]	0.393
IPI Ice Cream, index (1997=100)	-0.158	0.252
R^2	0.937	
Number of Observations	238	

Note: a, b and c denotes significance at the 1%, 5% and 10% levels, respectively.

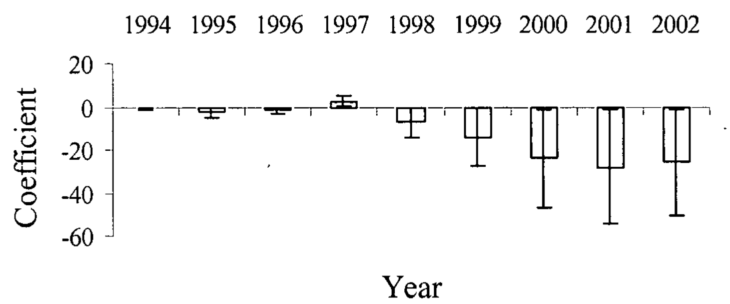


Figure 5.3: Coefficients on the Year Dummies in the Specialty Cheese Equation

Table 5.5: Reduced Form Demand for Yogurt (equation 4.4)

Dependent Variable: Yogurt, 1,000,000 kg		
Variable	**Coefficient**	**Standard Error**
Lagged Yogurt, 1,000,000 kg	0.255[a]	0.055
Unemployment, 100,000 individuals	-0.017	0.093
Population, 100,000 individuals	-0.028	0.031
Income, 100 dollars	0.051	0.105
CPI, index (1992=100)	-0.180[a]	0.042
CPI Cheese, index (1992=100)	0.108[a]	0.030
CPI Dairy Products, index (1992=100)	0.008	0.029
IPI Ice Cream, index (1997=100)	-0.049[a]	0.019
R^2	0.903	
Number of Observations	238	

Note: a, b and c denotes significance at the 1%, 5% and 10% levels, respectively.

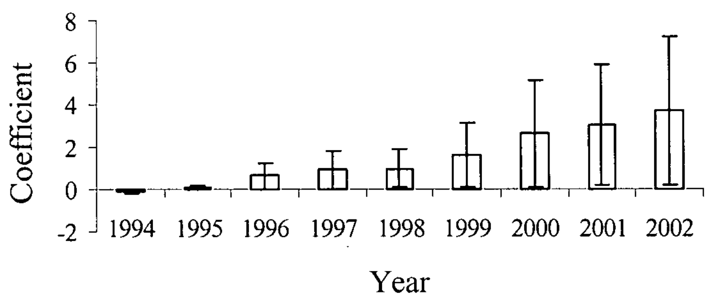


Figure 5.4: Coefficients on the Year Dummies in the Yogurt Equation

Table 5.6: Reduced Form Demand for Ice Cream (equation 4.5)

Dependent Variable: Ice Cream, 576,700 lt		
Variable	**Coefficient**	**Standard Error**
Lagged Ice Cream, 576,700 lt	0.488[a]	0.043
Unemployment, 100,000 individuals	1.517[b]	0.593
Population, 100,000 individuals	-0.343[b]	0.192
Income, 100 dollars	1.703[a]	0.661
CPI, index (1992=100)	0.541[b]	0.281
CPI Cheese, index (1992=100)	-0.282	0.187
CPI Dairy Products, index (1992=100)	-0.223	0.181
IPI Ice Cream, index (1997=100)	0.017	0.116
R^2	0.918	
Number of Observations	238	

Note: a, b and c denotes significance at the 1%, 5% and 10% levels, respectively.

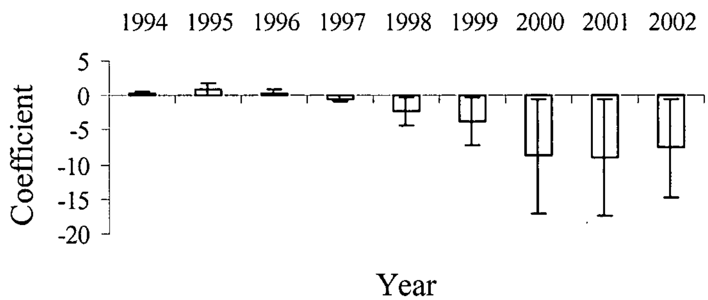


Figure 5.5: Coefficients on the Year Dummies in the Ice Cream Equation

Table 5.7: Casein Price (equation 4.6)

Dependent Variable: Casein Price, dollars/kg		
Variable	**Coefficient**	**Standard Error**
U.S. Milk Price, U.S. dollars/hl	0.031	0.023
U.S. Wage, U.S. dollars/hour	-0.136	0.474
U.S. Energy, index (Jan 1998=100)	-0.019	0.014
Exchange Rate, CAD/USD	3.441	2.360
R^2	0.403	
Number of Observations	238	

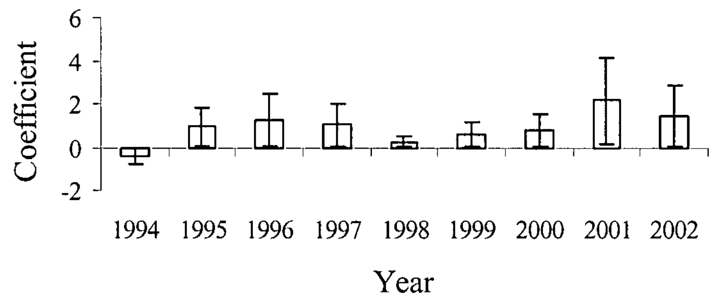


Figure 5.6: Coefficients on the Year Dummies in the Casein Price Equation

7. CONCLUSION

This thesis uses theoretical and empirical analysis to examine the effects of supply management on quality in the dairy industry, thereby filling a gap in the literature. Specifically, for the theoretical model I examine the effect of supply management on cheese quality, quantity produced and number of firms in the industry using some comparative statics analysis. For the empirical model, I use the derived demand equation for casein as a function of the reduced form demand for the outputs (cheddar, specialty cheese, yogurt and ice cream), the marginal costs (milk price, wage and metal) and the number of plants to determine the effect of high levels of protection on product quality.

Most of the empirical results match the theoretical ones. In both models, evidence suggests that supply management negatively affects cheese quality. In the theoretical model, supply management, by increasing marginal costs, increases the quantity of extended cheese produced. In the empirical model, the quantity of casein imports increases in response to an increase in the price of milk. The results of the empirical model suggest that approximately 9.8% of specialty cheese is produced using casein. Furthermore, I estimate the amount of milk displaced by casein if milk price increases one dollar, 722.65 hl of milk per month; and the implied spillover effect on Canadian dairy farmers, which, on average, decreases their revenue by 33,033 dollars per month.

The results, regarding the number of plants, of the two models differ. In the theoretical model, there is a decrease in the total number of firms and an increase in the fraction of firms entering the extended market. More firms and firms with higher fixed costs will be able to adopt the technology and produce extended cheese. On the other hand, in the empirical analysis, I find that a decrease in the number of plants decreases the quantity of casein. Removing one plant from the market is associated with a 140 kg (0.21% of the average monthly casein imports) decrease in casein imports. Over the time–frame of this study, the dairy processing industry has undergone a great deal of rationalization. Economies of scale and scope, which enable firms to lower costs without the need to use extenders in the products, are one possible explanation for this rationalization. Another possible explanation is that market power allows firms to better capture revenue associated with quality.

The overall results of the theoretical model suggest that supply management yields cheese of lower quality. The empirical analysis, does not offer such a strong conclusion because many factors affect the results. It is generally accepted that supply management has increased the price of milk (as discussed in the Literature Review). Consequently, I find evidence that supply management has increased imports of casein (2,170 kg for each dollar/hl, which is 3.34% of the average monthly casein imports), while decreasing farmers' revenue (due to the spillover effect) and cheese quality. In December 2002, imports of casein increased by 35,294 kg (54.4% of the average monthly casein imports) given the relatively higher Canadian milk price (compared to the U.S. milk price) due to supply management. This means that 11,765 hl of milk have been displaced, causing the spillover effect to decrease farmers' revenue by 634,358 dollars.

The spillover effect for Quebec in December 2002 is 1.81% of the extra revenue produced by supply management due to the higher Canadian milk price compared to the U.S milk price. This evidence suggests that supply management is negatively affecting cheese quality. However, in August 2000, Canada eliminated the export program because of WTO negotiations. This effect is captured in the dummy variable for the years 2000 to 2002. The coefficient is positive, suggesting that the export program affects imports of casein. This effect is causing the greatest spillover effect decreasing farmers' revenue. This is because processors that want to continue exporting need to explore alternative production techniques to keep costs low. The availability of technology to extend cheese contributed to the increase in casein imports.

This area requires further study, since casein imports are not subject to import tariffs. Import tariffs (or reclassification), for example, a 50% *ad valorem* tariff would decrease casein imports by 145,514 kg (224% of the average monthly casein imports), translating into 48,505 hl more milk being used in cheese processing and an average increase in farmers' revenue of 2,217,141 dollars. To drive casein imports down to zero, a 22% *ad valorem* tariff is needed. Another interesting issue is whether casein will be produced again in Canada.

The processing industry is able to charge higher prices for their products due to supply management. As mentioned in the Literature Review, evidence suggests that the processing sector has a significant degree of market power (Rude and Goddard, 1995). Regulations in Canada, together with the worldwide consolidation trend, have allowed dairy processors to charge higher prices. Furthermore, processors are able to price and quality discriminate among consumers using different brands. Unfortunately, at this stage, I cannot incorporate this effect into the study, but it is an area open for further consideration.

Currently, there are more and better (in terms of taste and appearance) substitutes, made from alternative sources, for traditional products. However, this does not mean that products are of higher quality. Actually, in most cases it is the other way around. The incentive for firms to launch substitute products is to create niche markets to obtain better profits for lower–cost products. This incentive is exacerbated by regulations that increase the price of traditional ingredients, while allowing low–cost substitutes to be imported barrier–free. These regulations have a significant effect on the quality of the end product and farmers' revenue.

REFERENCES

Annual Dairy Trade Bulletin (2001). Agriculture and Agri–Food Canada. <http://www.dairyinfo.gc.ca/pdf_files/bulletin01.pdf>

Acharyya, R. (1998). Monopoly and Product Quality: Separating or Pooling Menu? Economic Letters. 61(2): 187-194.

Barichello, R. R. (1981). The Economics of Canadian Dairy Industry Regulation. Economic Council of Canada Technical Report #E/12.

_____. (1996). Capitalising Government Program Benefits: Evidence of the Risk Associated with Holding Farm Quotas. The Economics of Agriculture, Vol. 2. Papers in Honour of D. Gale Johnson. Edited by John M. Antle and Daniel A. Sumner. The University of Chicago Press, U.S.A. 283-299.

_____. (1999). The Canadian Dairy Industry: Prospects for Future Trade. Canadian Journal of Agricultural Economics. 47(5): 45-55.

Barichello, R. R. and B. K. Stennes (1994). Cost Competitiveness of the Canadian Dairy Industry: A Farm Level Analysis. Paper prepared for the "Supply Management in Transition" Conference, Quebec, Canada, June 28-30, 1994.

Beath, J. and Y. Katsoulacos (1991). The Economic Theory of Product Differentiation. Cambridge University Press, First Edition, Great Britain. 75-83.

Brander, J. A. and B. J. Spencer (1984). Export Subsidies and International Market Share Rivalry. NBER Working Paper 1464.

CDC's Stakeholder Consultations on the Market Situation for Dairy Products in Canada (2002). Prepared by the Canadian Dairy Commission. June 3, 2002.

CDC (2003). Canadian Dairy Commission. <http://www.cdc.ca/>

Canadian Dairy Commission Annual Report 2001-2002. <http://www.cdc.ca/>

Canadian Dairy Industry Profile (2002). Agriculture and Agri–Food Canada. <http://www.dairyinfo.gc.ca/pdf_files/dairyprofile.pdf>

CITT (1998). Canadian International Trade Tribunal, Profile of the Canadian Dairy Industry. Staff Report (GC-91-001). March 16, 1998.

DFAIT (2003). Department of foreign affairs and international trade. <http://www.dfait-maeci.gc.ca/>

Dairy Market Review (2001). Agriculture and Agri–Food Canada. < http://www.dairyinfo.gc.ca/pdf_files/dmr2001.pdf>

Dairy Trade Bulletin – Dairy Year 2001-2002. Agriculture and Agri–Food Canada. <http://www.dairyinfo.gc.ca/pdf_files/bulletin0102.pdf>

Emmons, D. B. and H. W. Modler (2000). Introduction to Multiple–Component Milk Pricing. Agriculture and Agri–Food Canada.

Ewing, R. (1994). The Canadian Dairy Industry: Institutional Structure and Demand Trends in the Nineties. Economic Policy Analysis and Innovation Division, Policy Branch, Agriculture Canada, Working Paper 1/94.

Food Bureau (2003). The Canadian Dairy Processing Industry Sub–sector Profile. Agriculture and Agri–Food Canada. October 10, 2003. <http://www.agr.gc.ca/food/profiles/dairy/dairy_e.html>

Greene, W. H. (1994). Econometric Analysis. Prentice–Hall Inc., Fourth Edition, U.S.A. 462-463.

Ishikawa, J. and B. J. Spencer (1996). Rent Shifting Export Subsidies with an Imported Intermediate Product. NBER Working Paper 5458.

Lambertini, L. (1998). Does Monopoly Undersupply Product Quality? Working Papers from Universita degli Studi di Bologna. <http://www.dse.unibo.it/wp/317.pdf>

Mangold, P. (2001). Milk Proteins and More. Presentation prepared for La foundation des Gouverneurs, October 31, 2001.

Meilke, K., R. Sarker and D. Le Roy (1998). The Potential for Increased Trade in Milk and Dairy Products between Canada and the United States under Trade Liberalization. Canadian Journal of Agricultural Economics. 46(2): 149-169.

Milk Ingredients (2003). Agriculture and Agri–Food Canada. <http://www.milkingredients.ca/>

Potter, N. N. and J. H. Hotchkiss (1995). Food Science. AVI Publishing Company, Fifth Edition, U.S.A. 279-315.

Richards, T. J. (1996). The Effect of Supply Management on Dairy Productivity. The Canadian Journal of Economics. 29(Special Issue Part 2): S458-S462.

Richards, T. J. and S. R. Jeffrey (1997). The Effect of Supply Management on Herd Size in Alberta Dairy. American Journal of Agricultural Economics. 79(2): 555-565.

Romain, R. (2001). The Future of the Dairy Industry in Canada. Discussion Series SD.01.01 Centre de Recherché en Economie Agroalimentaire Universite Laval.

Rude, J. and E. W. Goddard. 1995. Analysis of the Cost Structure for Processed Products: The Case of the Canadian Dairy Processing Sector. Working Paper WP95/05 Department of Agricultural Economics and Business, University of Guelph.

Schmitz, A. and T. G. Schmitz (1994). Supply Management: The Past and Future. Canadian Journal of Agricultural Economics. 42(2): 125-148.

StataCorp. (2001). Stata Statistical Software: Release 7.0. College Station, TX: Stata Corporation. Reference Manual Volume 3: 44-63.

Statistics Canada. < http://www.statcan.ca/>

Task Force on National Dairy Policy (1990). Consultative Document. July 10, 1990.

Task Force on National Dairy Policy (1991). Evolution of the Canadian Dairy Industry. May 31, 1991.

USDA Economic Research Service. <http://www.ers.usda.gov/Briefing/Dairy/>

U.S. Department of Labour, Bureau of Labour Statistics. <http://www.bls.gov/data/home.htm>

Vercammen, J. and A. Schmitz (1994). Deregulating Supply–Managed Industries: The Unexpected Trade Effects. Paper presented at "Supply Management in Transition Towards the 21st Century", June 28-30, 1994, Quebec, Canada.

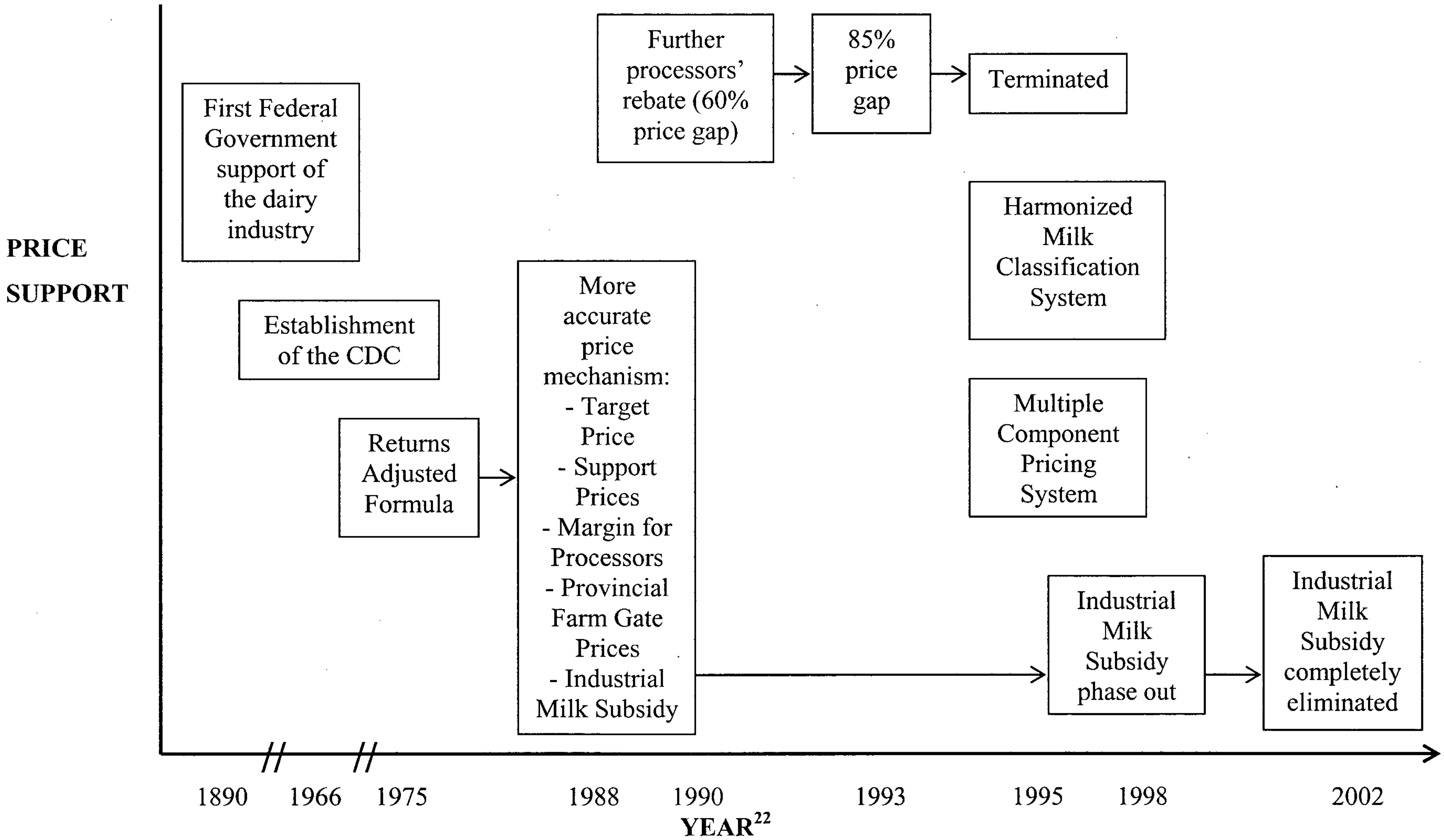
Western Dairy Digest (2001). Volume 2 Number 3, Spring 2001. <http://www.westerndairyscience.com>

Western Dairy Digest (2003). Volume 4 Number 3, Spring 2003. <http://www.westerndairyscience.com>

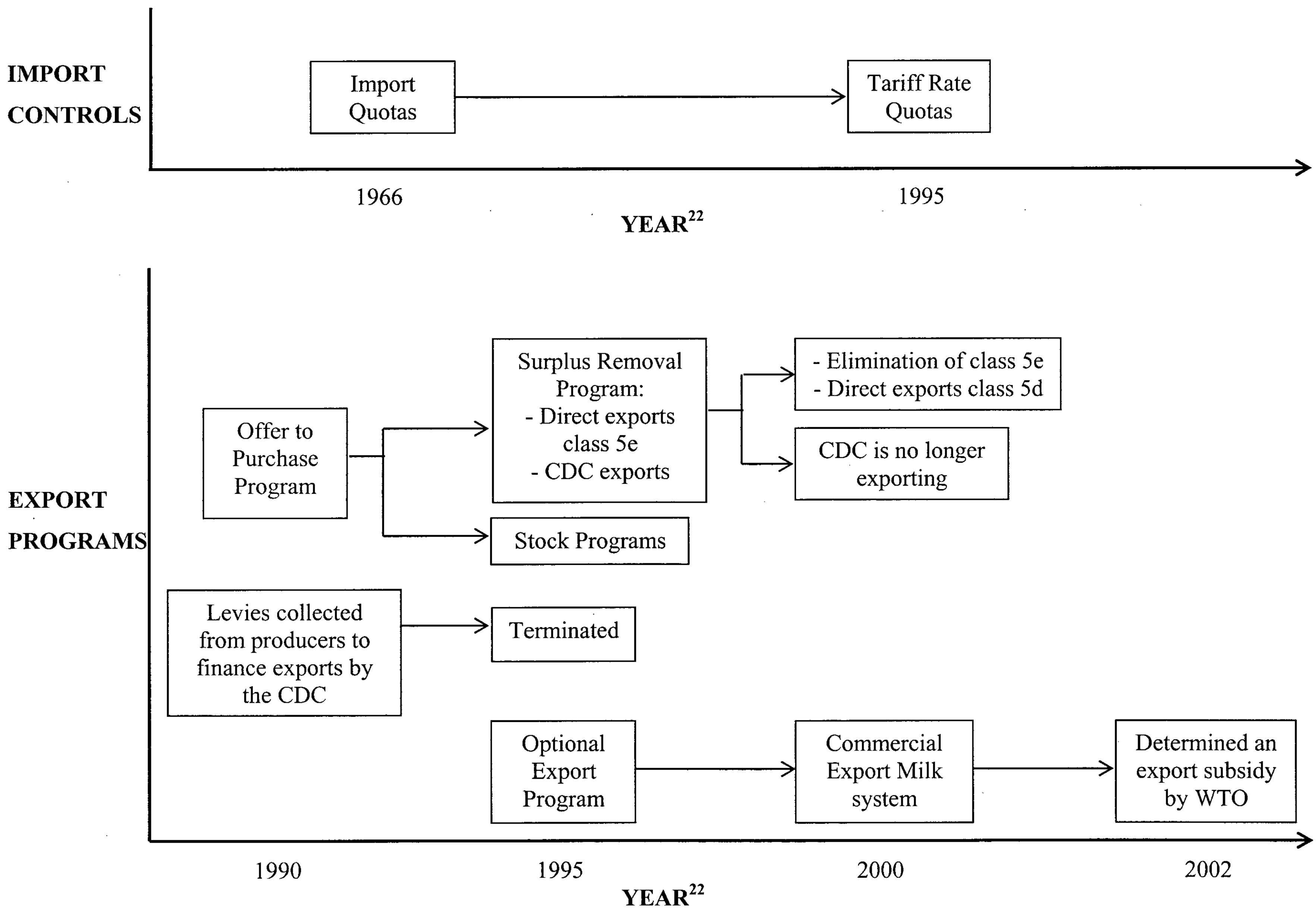
Whipple, G. D. (1983). Pricing Policy. American Journal of Agricultural Economics. 65(2): 209-213.

Wilson, B. (2003). Dairy farmers want butteroil problem fixed. The Western Producer, April 25, 2003. < http://www.producer.com/>

APPENDIX I: Supply Management System Flowchart



[22] Not to scale.


IMPORT CONTROLS
Import Quotas
Tariff Rate Quotas
1966
1995
YEAR22
EXPORT PROGRAMS
Offer to Purchase Program
Surplus Removal Program:
- Direct exports class 5e
- CDC exports
Stock Programs
- Elimination of class 5e
- Direct exports class 5d
CDC is no longer exporting
Levies collected from producers to finance exports by the CDC
Terminated
Optional Export Program
Commercial Export Milk system
Determined an export subsidy by WTO
1990
1995
2000
2002
YEAR22

APPENDIX II

Harmonized Milk Classification System (CDC, 2003)

Class 1	a) Fluid milks b) Fluid creams c) Milk–based beverages d) Fluid milks for the Yukon, Nunavut, and Northwest Territories (supplied by Alberta and British Columbia)
Class 2	Yogurt, sour cream and ice cream
Class 3	a) Specialty cheeses b) Cheddar cheese
Class 4	a) Butter, butteroil, powders and concentrated milk for ingredient purposes b) Concentrated milk for retail c) New products for the domestic market d) Inventory milk and plant losses m) Domestic marginal markets
Class 5	a) Cheese for further processing b) All other dairy products for further processing c) Confectionery d) Planned exports

APPENDIX III

Dairy Products Definitions[23]

- **Cheddar Cheese**: the product made by coagulating milk, milk products or a combination thereof with the aid of bacteria to form a curd and subjecting the curd to the cheddar process or any other process other than the cheddar process that produces a cheese having the same physical, chemical and organoleptic properties as those of cheese produced by the cheddar process. It contains not more than 39 percent moisture and not less than 31 percent milk fat and may contain salt, bacterial cultures to aid in the further ripening, colour and other permitted agents. Cheddar is the principal cheese used to make process cheese.

- **Edible casein:** main protein of milk. Dry product obtained by separating, washing and drying coagulum of skimmed milk, here the coagulum is obtained by precipitating with food grade acid.

- **Processed cheese:** processed cheese or processed cheese spreads are made by grinding, mixing, melting and emulsifying with the aid of heat and emulsifying agents of some or more varieties of cheese with a selection of ingredients or additives.

- **Specialty cheese:** all those varieties of cheese other than cheddar, cottage and processed cheese.

- **Whey:** the liquid part of milk that remains after the separation of curd in cheese making.

[23] These definitions were taken from Canadian International Trade Tribunal (1998). Profile of the Canadian Dairy Industry. Staff Report (GC-91-001). March 16, 1998.

- **Yogurt:** coagulated milk product obtained by lactic acid fermentation through the action of Lactobacillus bulgaricus and Streptococcus thermophilus from milk and milk products. The micro–organisms in the final product must be viable and abundant.

APPENDIX IV

Comparative Statics Results

To obtain the comparative statics results, I totally differentiated the equilibrium equations 3.5, 3.6, 3.11 and 3.12. I substituted F^e, Q^n and Q^e using equations 3.13, 3.14 and 3.15 to obtain the results for n and θ^*. With the results of the total differentiation, I formed the corresponding matrix and used Cramer's rule to obtain the comparative statics results. The analytical solution was obtained using the Symbolic Math Toolbox in MATLAB 6.1. These are the equations obtained, where $0 < b, d, \lambda^0$ and $\lambda^1 > 1$ and H is the standard Hessian Matrix (positive by the concavity condition required to obtain a maximum):

$$\frac{dq^n}{dm^n} = \frac{0}{H} = 0 \qquad \text{(A4.1)}$$

$$\frac{dq^n}{dm^e} = \frac{0}{H} = 0 \qquad \text{(A4.2)}$$

$$\frac{dq^n}{dF^n} = -\frac{-\dfrac{[-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^2 q^n (q^e)^2}}{H} = \frac{+}{+} = + \qquad \text{(A4.3)}$$

In the top part of the numerator, all the expressions have a negative number, except bdF^e. Since $0 > b$ and $d < 1$, $F^e > bdF^e$, making the subtraction of these expressions negative. The bottom part of the numerator is positive, because the negative term is squared. The negative sign outside the parenthesis multiplying the negative sign on the top part make the whole numerator positive.

$$\frac{dq^n}{dK} = \frac{0}{H} = 0 \qquad \text{(A4.4)}$$

$$\frac{dq^e}{dm^n} = \frac{0}{H} = 0 \qquad \text{(A4.5)}$$

$$\frac{dq^e}{dm^e} = \frac{0}{H} = 0 \qquad \text{(A4.6)}$$

$$\frac{dq^e}{dF^n} = \frac{0}{H} = 0 \qquad \text{(A4.7)}$$

$$\frac{dq^e}{dK} = \frac{-\dfrac{[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b]}{(-1+bd)^2(q^n)^2 q^e}}{H} = \frac{+}{+} = + \qquad \text{(A4.8)}$$

The logic for the signing of this equation is the same as in equation A4.3.

$$\frac{dn}{dm^n} = \frac{\dfrac{n[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][F^e - bdF^e + (q^e)^2\lambda^0 + (q^e)^2\lambda^1 d]}{(-1+bd)^3(q^n)^2 q^e(\underline{\theta} - \bar{\theta})}}{H} \qquad \text{(A4.9)}$$

$$\frac{dn}{dm^n} = \frac{-}{+} = -$$

The sign on the top part of the numerator follows the same logic as in equation A4.3 (negative sign). The bottom part has a positive sign, since $(-1+bd)^3$ is negative ($bd < 1$), and is multiplying $(\underline{\theta} - \bar{\theta})$, which is negative as well ($\bar{\theta} > \underline{\theta}$).

$$\frac{dn}{dm^e} = \frac{\dfrac{-bn[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][F^e - bdF^e + (q^e)^2\lambda^0 + (q^e)^2\lambda^1 d]}{(-1+bd)^3(q^n)^2 q^e(\underline{\theta} - \bar{\theta})}}{H} \qquad \text{(A4.10)}$$

$$\frac{dn}{dm^e} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.9.

$$\frac{dn}{dF^n}=\frac{\dfrac{-n[n(q^e)^2\lambda^0+n(q^e)^2\lambda^1 d+nF^e-2nF^e bd+(q^e)^2(\lambda^0)^2+(q^e)^2\lambda^0\lambda^1 d+\lambda^0F^e-\lambda^0F^e bd+(q^e)^2\lambda^0\lambda^1 b+(q^e)^2(\lambda^1)^2 bd+F^e\lambda^1 b-F^e\lambda^1 b^2 d+nF^e b^2d^2-n(q^e)^2\lambda^0 bd-n(q^e)^2\lambda^1 bd^2]}{(-1+bd)^3q^nq^e(\underline{\theta}-\overline{\theta})}}{H} \tag{A4.11}$$

$$\frac{dn}{dF^n}=\frac{-}{+}=-$$

The logic for the signing of this equation is the same as in equation A4.9.

$$\frac{dn}{dK}=\frac{\dfrac{-(\lambda^0+\lambda^1 d)nb\theta^*[-F^n+bdF^n-(q^n)^2\lambda^0-(q^n)^2\lambda^1 b]}{(-1+bd)^3(q^n)^2(\underline{\theta}-\overline{\theta})}}{H}=\frac{+}{+}=+ \tag{A4.12}$$

The logic for the signing of this equation is the same as in equation A4.9.

$$\frac{d\theta^*}{dm^n}=\frac{\dfrac{-[-F^n+bdF^n-(q^n)^2\lambda^0-(q^n)^2\lambda^1 b][F^e-bdF^e+(q^e)^2\lambda^0+(q^e)^2\lambda^1 d][q^n d(\overline{\theta}-\underline{\theta})+q^e(\theta^*-\underline{\theta})]}{(-1+bd)^3(q^n)^2(q^e)^2(\underline{\theta}-\overline{\theta})}}{H}=\frac{+}{+}=+ \tag{A4.13}$$

The logic for the signing of this equation is the same as in equation A4.9. Also, $\theta^*>\underline{\theta}$.

$$\frac{d\theta^*}{dm^e}=\frac{\dfrac{[-F^n+bdF^n-(q^n)^2\lambda^0-(q^n)^2\lambda^1 b][F^e-bdF^e+(q^e)^2\lambda^0+(q^e)^2\lambda^1 d][q^n d(\overline{\theta}-\underline{\theta})+q^e(\theta^*-\underline{\theta})]}{(-1+bd)^3(q^n)^2(q^e)^2(\underline{\theta}-\overline{\theta})}}{H}=\frac{-}{+}=- \tag{A4.14}$$

The logic for the signing of this equation is the same as in equation A4.13.

$$\frac{d\theta^*}{dF^n} = \frac{\dfrac{\begin{gathered}[(q^e)^3(\lambda^0)^2(\theta^* - \underline{\theta}) + nF^e q^e b^2 d^2(\theta^* - \underline{\theta}) - n(q^e)^3\lambda^1 bd^2(\theta^* - \underline{\theta}) \\ - n(q^e)^3\lambda^0 bd(\theta^* - \underline{\theta}) + q^n(q^e)^2(\lambda^1)^2 bd^2(\theta^* - \underline{\theta}) \\ + (q^e)^3(\lambda^1)^2 bd(\theta^* - \underline{\theta}) + F^e q^n\lambda^1 bd(\overline{\theta} - \underline{\theta}) + F^e q^e\lambda^1 b(\theta^* - \underline{\theta}) \\ - F^e q^n\lambda^1 b^2 d^2(\overline{\theta} - \underline{\theta}) - F^e q^e\lambda^1 b^2 d(\theta^* - \underline{\theta}) + n(q^e)^3\lambda^1 d(\theta^* - \underline{\theta}) \\ - 2nF^e q^e bd(\theta^* - \underline{\theta}) + q^n(q^e)^2(\lambda^0)^2 d(\overline{\theta} - \underline{\theta}) + q^n(q^e)^2\lambda^0\lambda^1 d^2(\overline{\theta} - \underline{\theta}) \\ + (q^n)^3\lambda^0\lambda^1 d(\theta^* - \underline{\theta}) + F^e q^n\lambda^0 d(\overline{\theta} - \underline{\theta}) - F^e q^n\lambda^0 bd(\overline{\theta} - \underline{\theta}) \\ - F^e q^e\lambda^0 bd(\theta^* - \underline{\theta}) + q^n(q^e)^2\lambda^0\lambda^2 bd(\overline{\theta} - \underline{\theta}) + (q^e)^3\lambda^0\lambda^1 b(\theta^* - \underline{\theta}) \\ + n(q^e)^3\lambda^0(\theta^* - \underline{\theta}) + nF^e q^e(\theta^* - \underline{\theta}) + F^e q^e\lambda^0(\theta^* - \underline{\theta})]\end{gathered}}{(-1+bd)^3 q^n (q^e)^2(\underline{\theta} - \overline{\theta})}}{H} \tag{A4.15}$$

$$\frac{d\theta^*}{dF^n} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.13.

$$\frac{d\theta^*}{dK} = \frac{\dfrac{\begin{gathered}\theta^*[(q^e)\lambda^1 bd(\theta^* - \underline{\theta}) + q^e\lambda^0 b(\theta^* - \underline{\theta}) + nq^n(\theta^* - \underline{\theta}) - nq^n bd(\theta^* - \underline{\theta}) \\ + q^n\lambda^1 d(\theta^* - \underline{\theta}) + q^n\lambda^0(\theta^* - \underline{\theta})][-F^n + F^n bd - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b]\end{gathered}}{(-1+bd)^3(q^n)^2 q^e(\underline{\theta} - \overline{\theta})}}{H} \tag{A4.16}$$

$$\frac{d\theta^*}{dK} = \frac{-}{+} = -$$

The logic for the signing of this equation is the same as in equation A4.13.

$$\frac{dQ^n}{dm^n} = \frac{\dfrac{[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3(q^n)^2(q^e)^2}}{H} \tag{A4.17}$$

$$\frac{dQ^n}{dm^n} = \frac{-}{+} = -$$

The logic for the signing of the top part of the numerator is the same as in equation A4.3 (positive sign). The bottom part of the numerator is negative because of $(-1+bd)^3$, as explained in equation A4.9.

$$\frac{dQ^n}{dm^e} = \frac{\dfrac{-b[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3(q^n)^2(q^e)^2}}{H} \quad (A4.18)$$

$$\frac{dQ^n}{dm^e} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^n}{dF^n} = \frac{\dfrac{-(\lambda^0 + \lambda^1 b)[-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3 q^n (q^e)^2}}{H} \quad (A4.19)$$

$$\frac{dQ^n}{dF^n} = \frac{-}{+} = -$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^n}{dK} = \frac{\dfrac{b(\lambda^0 + \lambda^1 d)[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b]}{(-1+bd)^3(q^n)^2 q^e}}{H} \quad (A4.20)$$

$$\frac{dQ^n}{dK} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^e}{dm^n} = \frac{\dfrac{-d[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3(q^n)^2(q^e)^2}}{H} \quad (A4.21)$$

$$\frac{dQ^e}{dm^n} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^e}{dm^e} = \frac{\dfrac{[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b][-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3 (q^n)^2 (q^e)^2}}{H} \tag{A4.22}$$

$$\frac{dQ^e}{dm^e} = \frac{-}{+} = -$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^e}{dF^n} = \frac{\dfrac{d(\lambda^0 + \lambda^1 b)[-F^e + bdF^e - (q^e)^2\lambda^0 - (q^e)^2\lambda^1 d]}{(-1+bd)^3 q^n (q^e)^2}}{H} \tag{A4.23}$$

$$\frac{dQ^e}{dF^n} = \frac{+}{+} = +$$

The logic for the signing of this equation is the same as in equation A4.17.

$$\frac{dQ^e}{dK} = \frac{\dfrac{-(\lambda^0 + \lambda^1 d)[-F^n + bdF^n - (q^n)^2\lambda^0 - (q^n)^2\lambda^1 b]}{(-1+bd)^3 (q^n)^2 q^e}}{H} \tag{A4.24}$$

$$\frac{dQ^e}{dK} = \frac{-}{+} = -$$

The logic for the signing of this equation is the same as in equation A4.17.

APPENDIX V

Data Description

Most of the data used were obtained from Statistics Canada and are monthly by province (unless otherwise noted). Information regarding milk volumes and prices is recorded by the provincial marketing boards and agencies. The recent data are available to the public through the CDC webpage. Milk prices and volumes for 1998 to 2003 were obtained from the CDC webpage. The data from 1993 to 1997 were provided by Agriculture and Agri–Food Canada. Milk prices were all converted into dollars per hectolitre of milk and milk volumes into hectolitres. The U.S. data are monthly, obtained from the USDA Economic Research Service webpage and from the U.S. Department of Labour, Bureau of Labour Statistics webpage.

Only data from Ontario and Quebec were used. This is because the other provinces either were not producing some of the products, were not importing casein or, because of the small number of processing plants, production information was confidential. Also, as previously noted in the Industry Background section, these two provinces account for the majority of the dairy production (85%). This proportion of production is virtually fixed over the period studied. There are 238 observations, corresponding to ten years for the two provinces minus the two lost observations due to the lagged variables.

Casein is monthly quantity of casein imported in kilograms by province, obtained through the "Trade: Imports and Exports" section of Statistics Canada. There are no data available on casein price. The casein price used was computed by dividing casein import value by casein import quantity. In the cases where there are no casein imports (15 observations for Quebec), the average of the adjacent observations was used.

The following tables were obtained from the CANSIM section. Production data are monthly by province and come from Table 003-0010; the units are tonnes, except ice cream is in kilolitres. These units were scaled according to the yield mentioned in the Technical Background section so they would correspond to the yield from one hl of milk. Later, they were scaled again to obtain homogeneous results in terms of magnitude of the coefficients. Specifically, the units used to run the regressions are: cheese in 100,000 kg, yogurt in 1,000,000 kg and ice cream in 576,700 lt.

Metal Index is the index price for metal (primary steel products) for Canada by month, where 1997 equals 100 (Table 329-0044). The Table for wage is 281-0039; it is the fixed weighted index (1996=100) of average hourly earnings for all employees, unadjusted for seasonal variation, for selected industries (non–durables) classified using the North American Industry Classification System (NAICS), monthly, by province. The unemployment data come from Table 282-0001: "Labour force survey estimates (LFS), both sexes, 15 years and over, thousands of persons", scaled to 100,000 individuals, monthly, by province. The only population data available by province for the period of time studied are quarterly data (Table 051-0005: Estimates of population, Canada, provinces and territories, quarterly, persons). This data were transformed to a monthly basis by taking the difference by quarter, dividing it by 12 and adding it for each month. It was also scaled, to obtain units of 100,000 individuals.

Income comes from: "Average market income, by selected economic family types, by province, all family units, dollars, monthly" (Table 202-0202). This variable was also scaled, the final units are hundreds of dollars. Table 326-0001 is "Consumer Price Index (CPI), 2001 basket content, by province, all–items, monthly"; the index is 1992 equals 100. The CPI for cheese and dairy products were obtained from Table 326-0001: "Consumer price index, 2001 basket content, by province, monthly", where the index is 1992 equals 100. The IPI for ice cream and ice milk products comes from Table 329-0040 "Industry Price Indexes for Food, Meat, Fish and Dairy Products, Beverages and Tobacco, by province, monthly", the index is 1997=100. The exchange rate was obtained from Table 176-0064: "Foreign exchange rates in Canadian dollars, U.S. dollar, monthly".

The U.S. Milk Price was converted from U.S. dollars/cwt to U.S. dollars/hl, it is monthly and comes from the Prices section of the Dairy Yearbook in the USDA Economic Research Service. The U.S. wage is the average hourly earnings of production workers for manufacturing, non–durable goods industries, SIC codes 20-23 and 26-31, not seasonally adjusted, in U.S. dollars, monthly. It comes from the Employment, Hours, and Earnings from the Current Employment Statistics survey. The U.S. energy index was obtained from the Producer Price Index Commodity Data, Group: Fuels and related products and power, Item: Industrial electric power, the index is January 1982=100, monthly.

The number of dairy processing plants from 1993 to 1999 was obtained from the Manufacturing Census (Manufacturing Industries of Canada: National and Provincial Areas, Statistics Canada). The data for 2000 and 2001, from Table 301-0003: Annual Survey of Manufactures (ASM), principal statistics by NAICS. And finally, the information for 2002 was taken from the Canadian Dairy Industry Profile, 2002. These data are annual and is left constant through the year. Since there is no information regarding number of plants for 1996, I used an interpolation of the adjacent years. The code for dairy plants changed[24] in 1998 when Canada moved from the Standard Industrial Classification System (SIC) to the NAICS. Also, the methodology for the ASM changed in 2000 when the data universe was expanded to include all manufacturing units, instead of only recording data from manufacturing businesses over $30,000 in sales of manufactured goods and with employees. This change represented an increase of around 100% in the number of plants from 1999 to 2000. To obtain a consistent dataset, I transformed the number of plants from 1993 to 1999 to the new methodology based on the annual change from the old methodology. This transformation was done assuming the trend in the number of plants was the same for plants of all sizes.

The Harmonized Milk Classification System started in 1995. Prior to this, each province had a different classification system. This issue does not represent a problem, since a weighted price is used. The weighted price was calculated as a weighted average using prices and volumes for all classes. The volumes for each class are multiplied by the corresponding prices, summed and then divided by the summation of all volumes, thereby making the change in classes innocuous to the final result. The weighted price takes into account the lower (competitive) prices for the special classes. For Ontario, the milk price information is divided into four regions (Southern Ontario, Northern Ontario, Thunder Bay and North–western Ontario) for 1993 to 1994. I took the average for the prices by class.

Most of the data regarding milk prices are collected only in terms of the milk components (Ontario from October 1996 to December 2002, Quebec from January 1993 to December 1996 and from September 1997 to December 2002) or in terms of the differential (Ontario from January 1993 to September 1996). Price by class was obtained using the

[24] SIC code: 1040, NAICS code: 3115.

composition of milk according to the Supply Management Department of Agriculture and Agri–Food Canada (March 2004): butterfat 3.66 kg/hl, protein 3.2 kg/hl, other solids 5.68 kg/hl. The price for each component is multiplied by its content in milk and then added to the differential (if it is available).

Finally, as mentioned earlier, some variables were scaled to obtain homogeneous results in terms of magnitude of the coefficients. To achieve this, Casein, Cheddar, Specialty Cheese, Yogurt and Ice Cream were divided by 10,000; Unemployment and Income were divided by 100 and Population was divided by 100,000.

APPENDIX VI

Empirical Model Stata Code

The code used for the model described in chapter 4 (which corresponds to column II of Table 5.1) is the following:

```
reg3 (ched l.ched unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(spc l.spc unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(yog l.yog unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(icec l.icec unemployment population inc cpi cpi_cheese cpi_dp
ipi_ic tt tt2)(casein_p1 usmprice uswage usenergy exrate tt tt2)(casein
l.casein casein_p1 ched spc yog icec wp2 metalc fwiavghearn96_ndur dpiadj2
tt y00_02 gatt), exog(ched yog icec spc casein_p1)
```

The code used for the model presented in column I of Table 5.1 is:

```
reg3 (ched l.ched unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
m4_8 m12 _Iyear_1994 _Iyear_1995 _Iyear_1996 _Iyear_1997 _Iyear_1998
_Iyear_1999 _Iyear_2000 _Iyear_2001 _Iyear_2002)(spc l.spc unemployment
population inc cpi cpi_cheese cpi_dp ipi_ic m4_8 _Iyear_1994 _Iyear_1995
_Iyear_1996 _Iyear_1997 _Iyear_1998 _Iyear_1999 _Iyear_2000 _Iyear_2001
_Iyear_2002)(yog l.yog unemployment population inc cpi cpi_cheese cpi_dp
ipi_ic m4_8 m12 _Iyear_1994 _Iyear_1995 _Iyear_1996 _Iyear_1997 _Iyear_1998
_Iyear_1999 _Iyear_2000 _Iyear_2001 _Iyear_2002)(icec l.icec unemployment
population inc cpi cpi_cheese cpi_dp ipi_ic m3_8 _Iyear_1994 _Iyear_1995
_Iyear_1996 _Iyear_1997 _Iyear_1998 _Iyear_1999 _Iyear_2000 _Iyear_2001
_Iyear_2002)(casein_p1 usmprice uswage usenergy exrate _Iyear_1994
_Iyear_1995 _Iyear_1996 _Iyear_1997 _Iyear_1998 _Iyear_1999 _Iyear_2000
_Iyear_2001 _Iyear_2002)(casein l.casein casein_p1 ched spc yog icec wp2
metalc fwiavghearn96_ndur dpiadj2 _Iyear_1994 _Iyear_1995 _Iyear_1996
_Iyear_1997 _Iyear_1998 _Iyear_1999 _Iyear_2000 _Iyear_2001 _Iyear_2002),
endog(ched yog icec spc casein_p1)
```

The code used for the Tobit regression in column III is:

```
tobit casein lcas casp0 ched0 spc0 yog0 ic0 wp2 metalc fwiavghearn96_ndur
dpiadj2 tt y00_02 gatt, ll(0)
```

The code used to correct for heteroskedasticity is:

```
reg3 (ched l.ched unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(spc l.spc unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(yog l.yog unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(icec l.icec unemployment population inc cpi cpi_cheese cpi_dp
```

```
ipi_ic tt tt2)(casein_p1 usmprice uswage usenergy exrate tt tt2)(casein
l.casein casein_p1 ched spc yog icec wp2 metalc fwiavghearn96_ndur dpiadj2
tt y00_02 gatt), endog(ched yog icec spc casein_p1)
matrix VCM1=e(V)
matrix sigma=e(Sigma)
matrix s2=vecdiag(sigma)
predict cheddarhat1, eq(#1)
predict spchehat1, eq(#2)
predict yogurthat1, eq(#3)
predict icecreamhat1, eq(#4)
predict casphat1, eq(#5)
reg3 (ched l.ched unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(spc l.spc unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(yog l.yog unemployment population inc cpi cpi_cheese cpi_dp ipi_ic
tt tt2)(icec l.icec unemployment population inc cpi cpi_cheese cpi_dp
ipi_ic tt tt2)(casein_p1 usmprice uswage usenergy exrate tt tt2)(casein
l.casein casein_p1 ched spc yog icec wp2 metalc fwiavghearn96_ndur dpiadj2
tt y00_02 gatt), endog(ched yog icec spc casein_p1) 2sls
predict rched12, residuals eq(#1)
predict rspc12, residuals eq(#2)
predict ryog12, residuals eq(#3)
predict ricec12, residuals eq(#4)
predict rcasp12, residuals eq(#5)
predict rcas12, residuals eq(#6)
matrix input[25]
cheddar=(17801687.27,1367113.222,26958653.78,12507954.48,36935053.85,379484
14.21,37250148.46,33679353.78,9957977.885,291043888.6,343844.7271\1367113.2
22,119122.6124,2356628.006,1060849.979,3053700.852,3126505.201,3057214.511,
2785126.011,813030.841,23381706.05,28554.16252\26958653.78,2356628.006,4839
1700.49,21725856.68,61567441.38,62917003.2,61650044.86,55943750.64,16467147
.14,478765128.4,571802.541\12507954.48,1060849.979,21725856.68,9843735.263,
28096993.74,28745854.95,28203487.88,25510081.24,7543203.118,220465179.9,260
539.3818\36935053.85,3053700.852,61567441.38,28096993.74,81249590.8,8326551
9.94,81678011.19,73919962.92,21822854.67,636726510.2,755019.8877\37948414.2
1,3126505.201,62917003.2,28745854.95,83265519.94,85378773.73,83744743.11,75
781751.53,22373269.21,652912788.7,773879.9405\37250148.46,3057214.511,61650
044.86,28203487.88,81678011.19,83744743.11,82190063.9,74289168.73,21968071.
78,642272791.4,758451.1794\33679353.78,2785126.011,55943750.64,25510081.24,
73919962.92,75781751.53,74289168.73,67368933.16,19836861.61,577340887.1,687
906.9258\9957977.885,813030.841,16467147.14,7543203.118,21822854.67,2237326
9.21,21968071.78,19836861.61,5878660.362,172348208.1,202366.3582\291043888.
6,23381706.05,478765128.4,220465179.9,636726510.2,652912788.7,642272791.4,5
77340887.1,172348208.1,5097539190,5878660.362\343844.7271,28554.16252,57180
2.541,260539.3818,755019.8877,773879.9405,758451.1794,687906.9258,202366.35
82,5878660.362,7032.558728)
matrix input[25]
spcheese=(95721954.94,3751549.836,76863605.32,36729258.99,110190328.6,11467
9259.5,112611599.3,99105118.82,30161502.6,914007130.6,1004433.223\3751549.8
36,173542.428,3495699.335,1610495.893,4710516.644,4876204.352,4764677.559,4
263988.455,1269088.907,37432441.67,43492.3899\76863605.32,3495699.335,73286
762.18,33820162.94,97773393.92,101145898.7,99049407.59,88045222.13,26496834
.63,791886246.2,895468.5679\36729258.99,1610495.893,33820162.94,15756751.04
,45861337.98,47510950.74,46588085.01,41221635.31,12476549.69,375298219.5,41
8806.0444\110190328.6,4710516.644,97773393.92,45861337.98,134841797.7,13989
0829.6,137186834.2,121300156.1,36714219.22,1104574579,1232244.963\114679259
```

[25] The matrix input for each equation is the computation of equation A7.1 (Appendix VII) in EXCEL.

```
.5,4876204.352,101145898.7,47510950.74,139890829.6,145201271.6,142402106.6,
125851816.2,38112571.8,1147462748,1278160.049\112611599.3,4764677.559,99049
407.59,46588085.01,137186834.2,142402106.6,139721442.6,123333454.1,37405786
.78,1128037762,1252296.793\99105118.82,4263988.455,88045222.13,41221635.31,
121300156.1,125851816.2,123333454.1,109367789.4,32989866.12,989314144.5,111
0785.742\30161502.6,1269088.907,26496834.63,12476549.69,36714219.22,3811257
1.8,37405786.78,32989866.12,10022587.15,302882380.6,334757.2196\914007130.6
,37432441.67,791886246.2,375298219.5,1104574579,1147462748,1128037762,98931
4144.5,302882380.6,9232247832,10022587.15\1004433.223,43492.3899,895468.567
9,418806.0444,1232244.963,1278160.049,1252296.793,1110785.742,334757.2196,1
0022587.15,11292.90581)
matrix input25
yogurt=(1577.54224,1096.53261,24201.91605,11257.60336,32335.44833,33272.354
26,32783.47644,29111.64674,8807.801575,265055.6139,294.9181491\1096.53261,9
65.7814564,20716.24745,9276.412811,26117.78111,26738.70887,26158.72306,2369
2.29354,6976.924433,203482.8115,241.535304\24201.91605,20716.24745,462385.3
766,206448.7164,570563.9753,582662.5434,571395.0138,514964.1382,153199.2293
,4524362.039,5233.981395\11257.60336,9276.412811,206448.7164,92924.79253,25
8912.5233,264806.8552,259898.4091,233612.7068,69709.46749,2065662.246,2373.
075384\32335.44833,26117.78111,570563.9753,258912.5233,733338.3558,751991.2
325,737507.8811,663395.6977,197401.4281,5829956.671,6743.201831\33272.35426
,26738.70887,582662.5434,264806.8552,751991.2325,771708.5321,756713.6109,68
0724.8708,202489.6575,5978983.969,6917.883007\32783.47644,26158.72306,57139
5.0138,259898.4091,737507.8811,756713.6109,742423.8022,667095.1873,198757.8
461,5879354.258,6777.903004\29111.64674,23692.29354,514964.1382,233612.7068
,663395.6977,680724.8708,667095.1873,601364.8201,178436.0935,5256039.195,61
10.665665\8807.801575,6976.924433,153199.2293,69709.46749,197401.4281,20248
9.6575,198757.8461,178436.0935,53268.41575,1579635.635,1811.603367\265055.6
139,203482.8115,4524362.039,2065662.246,5829956.671,5978983.969,5879354.258
,5256039.195,1579635.635,47215821.86,53268.41575\294.9181491,241.535304,523
3.981395,2373.075384,6743.201831,6917.883007,6777.903004,6110.665665,1811.6
03367,53268.41575,62.1663508)
matrix input25
icecream=(1485768.378,274690.9517,6744283.425,2783502.71,6689056.159,665112
2.662,6527879.939,5918040.725,1763529.069,51808991.96,60641.12479\274690.95
17,62198.30381,1413503.368,584007.0282,1443919.367,1445847.094,1414529.557,
1290633.049,377747.4707,10849290.77,13298.34367\6744283.425,1413503.368,338
18510.72,14018565.82,34152778.93,34073863.46,33399929.66,30346296.28,899851
9.449,262719378.3,311356.605\2783502.71,584007.0282,14018565.82,5829762.733
,14234533.32,14202353.77,13926829.85,12641178.67,3757417.389,110026004.9,12
9603.5021\6689056.159,1443919.367,34152778.93,14234533.32,35101583.31,35090
287.32,34376978.14,31258827.32,9256164.868,269912972.5,320625.1903\6651122.
662,1445847.094,34073863.46,14202353.77,35090287.32,35104207.55,34372778.67
,31281993.87,9249194.525,269266771.2,320896.0418\6527879.939,1414529.557,33
399929.66,13926829.85,34376978.14,34372778.67,33679145.69,30615026.16,90660
69.724,264373836.6,314049.5672\5918040.725,1290633.049,30346296.28,12641178
.67,31258827.32,31281993.87,30615026.16,27902151.05,8234400.381,239326829.3
,286137.083\1763529.069,377747.4707,8998519.449,3757417.389,9256164.868,924
9194.525,9066069.724,8234400.381,2446325.862,71641515.02,84355.50665\518089
91.96,10849290.77,262719378.3,110026004.9,269912972.5,269266771.2,264373836
.6,239326829.3,71641515.02,2117718128,2446325.862\60641.12479,13298.34367,3
11356.605,129603.5021,320625.1903,320896.0418,314049.5672,286137.083,84355.
50665,2446325.862,2938.433479)
matrix input25
caseinprice=(4305223.034,420758.5688,916931.6086,47212.26278,948967.3152,28
189678.93,32201.37618\420758.5688,41331.1797,89468.46321,4629.220897,93249.
98213,2784689.685,3146.129627\916931.6086,89468.46321,199386.341,10068.4180
```

```
4,201781.0679,5974933.518,6867.38192\47212.26278,4629.220897,10068.41804,51
9.1755154,10443.31614,311109.8017,353.2530763\948967.3152,93249.98213,20178
1.0679,10443.31614,210417.3296,6286032.035,7095.964537\28189678.93,2784689.
685,5974933.518,311109.8017,6286032.035,189078958.7,210417.3296\32201.37618
,3146.129627,6867.38192,353.2530763,7095.964537,210417.3296,241.2218864)
matrix input[25]
casein=(1788070.047,548813.3434,3419391.919,6048130.354,380705.8067,1335846
.805,3676735.944,7803327.8,8554887.923,10309506.35,2419298.141,49627.46807,
78352.82794,79387.48715\548813.3434,385561.6947,2544115.976,4600345.045,271
263.307,767733.4781,2554381.083,5547622.902,6047720.736,7258553.704,1686836
.892,26790.89189,54473.20558,56628.30371\3419391.919,2544115.976,17641546.3
3,32482236.9,1828895.391,4496558.469,16721187.41,36835960.76,39995089.44,46
678157.79,11118873.13,162069.5594,359393.692,375577.2913\6048130.354,460034
5.045,32482236.9,60936321.56,3355784.347,7632089.577,30077872.27,66721230.3
2,72327191.32,83514233.2,20088172.81,278370.235,654369.1942,679235.607\3807
05.8067,271263.307,1828895.391,3355784.347,201815.5775,478704.2285,1784702.
075,3858920.461,4251874.603,4944269.788,1189696.924,21270.22887,38276.8619,
39452.22723\1335846.805,767733.4781,4496558.469,7632089.577,478704.2285,225
4308.516,5192422.345,11146649.89,12056523.73,15587963.75,3372369.063,52251.
97227,108980.413,113696.3725\3676735.944,2554381.083,16721187.41,30077872.2
7,1784702.075,5192422.345,17088940.25,36819667.29,40102562.71,48797819.74,1
1179573.33,177878.0872,358874.2945,376034.155\7803327.8,5547622.902,3683596
0.76,66721230.32,3858920.461,11146649.89,36819667.29,80409234.72,87171795.5
6,105282958.4,24265910.18,360459.1891,786578.6331,819286.9648\8554887.923,6
047720.736,39995089.44,72327191.32,4251874.603,12056523.73,40102562.71,8717
1795.56,94966693.87,114080253.9,26474347.8,416801.9966,853771.093,889695.96
06\10309506.35,7258553.704,46678157.79,83514233.2,4944269.788,15587963.75,4
8797819.74,105282958.4,114080253.9,143259768.5,31761722.61,475342.8364,1022
606.586,1073872.345\2419298.141,1686836.892,11118873.13,20088172.81,1189696
.924,3372369.063,11179573.33,24265910.18,26474347.8,31761722.61,7387761.971
,119199.0226,238434.3833,247691.1815\49627.46807,26790.89189,162069.5594,27
8370.235,21270.22887,52251.97227,177878.0872,360459.1891,416801.9966,475342
.8364,119199.0226,3723.419242,3723.419242,3723.419242\78352.82794,54473.205
58,359393.692,654369.1942,38276.8619,108980.413,358874.2945,786578.6331,853
771.093,1022606.586,238434.3833,3723.419242,7981.964126,7981.964126\79387.4
8715,56628.30371,375577.2913,679235.607,39452.22723,113696.3725,376034.155,
819286.9648,889695.9606,1073872.345,247691.1815,3723.419242,7981.964126,835
9.76073)
matrix c0=J(11,54,0)
matrix s10=J(11,11,0)
matrix s20=J(11,43,0)
matrix y10=J(11,22,0)
matrix y20=J(11,32,0)
matrix i10=J(11,33,0)
matrix i20=J(11,21,0)
matrix cp10=J(7,44,0)
matrix cp20=J(7,14,0)
matrix ca0=J(14,51,0)
matrix c=cheddar,c0
matrix s=s10,spcheese,s20
matrix y=y10,yogurt,y20
matrix i=i10,icecream,i20
matrix cp=cp10,caseinprice,cp20
matrix ca=ca0,casein
matrix white=c\s\y\i\cp\ca
matrix VC=VCM1*white*VCM1
matrix se2=vecdiag(VC)
```

APPENDIX VII

Heteroskedasticity Correction

Heteroskedasticity problems were addressed using a modified version of the White method (Greene, 2000) to correct the variance–covariance matrix to obtain robust standard errors. The equations used are the following:

$$S_1 = \sum_{i=1}^{n} e_i^2 z_i z_i' \qquad \text{(A7.1)}$$

$$\hat{\Sigma} = \frac{E'E}{n} \qquad \text{(A7.2)}$$

$$V_{\hat{B}} = \{\hat{Z}'(\hat{\Sigma}^{-1} \otimes I)\hat{Z}\}^{-1} \qquad \text{(A7.3)}$$

$$\hat{V}_{\hat{B}} = \{\hat{Z}'(\hat{\Sigma}^{-1} \otimes I)\hat{Z}\}^{-1} S_1 \{\hat{Z}'(\hat{\Sigma}^{-1} \otimes I)\hat{Z}\}^{-1} \qquad \text{(A7.4)}$$

where:

n = number of observations

e = residuals

z = vector of right hand side variables and instruments

Z = matrix of right hand side variables and instruments

E = matrix of residuals

I = identity matrix

Equation A7.1 is the modified White correction to suit the model and estimation procedure, equations A7.2 and A7.3 are the specific equations for three–stage least squares (StataCorp. 2001) and equation A7.4 is the robust variance–covariance matrix used to compute the standard errors.

Once computed the robust variance–covariance matrix (called VC in Appendix VI), the square root of the diagonal elements (called se2 in Appendix VI) for each equation in the model were divided by the corresponding diagonal element of the sigma matrix ($\hat{\Sigma}$, called sigma in Appendix VI) to obtain robust standard errors. This procedure was done to correct for multiplying two times by the sigma matrix.