NAFTA and Virtual Water Trade:
An estimation of virtual water trade in livestock and livestock products between Canada and the United States

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.
I understand that my thesis may be made electronically available to the public.

Nabeela A. Rahman

Abstract

Canadian agriculture trade with the United States, specifically trade in livestock and livestock commodities, has flourished under the NAFTA regime. However, the benefits of this trade liberalization have hidden environmental costs that seldom get noticed or accounted. The purpose of this research was to evaluate the hidden cost on water resources by first assessing the virtual water content (VWC) of various types of livestock and livestock products and then quantifying the virtual water flow (VWF) related to trade in livestock and its products between Canada and United States. The study also examined the North American Free Trade Agreement (NAFTA) and evaluated its implications for Canadian water resources.

The research was conducted in three parts. First, the background literature on NAFTA was studied and trade data were collected to understand the NAFTA regime and study the impacts on Canadian exports of livestock and livestock products from the 1990s. The trade data were collected from provincial agricultural ministries and Statistics Canada. Secondly, datasheets were created to calculate the VWC in the various categories of animals and ultimately to estimate VWF between the two countries. Finally, Alberta and Ontario were chosen as case study areas to investigate localized impacts on water resources due to trade under NAFTA.

The research results indicate that there is a large difference in the amount of VW being transferred through livestock and livestock commodities from Canada to the U.S. The average difference in trade has been calculated to be 3.6 billion m^3 per year. This makes Canada a net exporter of virtual water to the U.S. A closer look at the trade patterns reveals that the U.S. imports mostly water-intensive commodities like cattle and cattle commodities, while it exports mostly less-water intensive commodities like chicken and mutton. By eliminating numerous trade barriers, the agreement has allowed competitive market forces to play a more dominant role in determining agricultural trade flows between the two countries.

NAFTA has been criticized and contested at different levels for encouraging bulk water export from Canada to the U.S. What has not received attention in this debate is that water is also being exported in other forms, i.e., the virtual form. The hidden environmental, costs (for the exporting countries) or benefits (to the importing countries) are not reflected in the pricing of agricultural commodities. NAFTA's mandate for the expansion of trade and investment through the removal of all trade barriers between the two countries is encouraging increased VW trade. This trade, if overlooked, can have deleterious impacts on the water resources of Canada.

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1 The Research Problem

1.1 Preface

According to neoclassical economics, the expansion of international trade fosters economic growth. The efficient allocation of resources through free trade based on comparative advantages encourages world economic growth. For Canada, this theory has been proven true. Free trade agreements with the United States and Mexico have helped Canada boost its economy, in monetary terms, since their adoptions in the late 1980s. However, the benefits of trade liberalization have hidden environmental costs that seldom get noticed or accounted. It is extremely important to understand the 'external' environmental costs of free trade and its impact on natural resources.

1.2 Rationale

Canada's agri-food business has experienced gains of over 92% in its export value over the last decade (Ash, 2005). This growth has primarily been facilitated by the Canada-U.S. Free Trade Agreement (CUSFTA) and later by the North American Free Trade Agreement (NAFTA), which established a single trade zone between the U.S., Canada and Mexico. Perhaps the largest growth was experienced by the livestock sector. Between 1993 and 2002, the sector showed an almost 230% increase in export value (Ash, 2005). Canada ranks third globally in terms of export of meat and meat products (Chapagain & Hoekstra, 2003) with almost 90% of exports going to the U.S. However, the meat industry is an extremely water-intensive industry. It was estimated by de Loë (2005) that the livestock sector accounted for 30% of the total agricultural water use in 2001 for the province of Ontario. The livestock industry has also been expanding rapidly in western Canada, particularly in Alberta, where many Intensive Livestock Operations (ILOs, large number of cattle, swine or poultry concentrated in a small area) are in place. According to Alberta Agriculture, Food and Rural Development, a minimum of 1.5- 3.0 litres/second of water needs to be pumped annually to meet the demand for 5000-20000 steers during peak demands in ILOs (Coote & Gregorich, 2000). This type of demand puts significant stress on water resources in these semi-arid regions. Thus, Canada is facing the most common effect associated with trade liberalization: increased production and consumption leading to increased pressure on natural resources.

Many critics of the free trade agreements such as Wendy Holm and Maude Barlow (Barlow, 2005; Holm, 1988; Holm, 1993) have always claimed that the free trade agreements have compromised Canada's sovereignty over water resources. By signing the FTAs, Canada has "turned on the tap" to the United States, by virtue of inclusion of water under the term "good" mentioned in tariff heading 22.0.1. However, this issue is a highly controversial and continues to be debated (Johansen, 2001; Johnson, 1994). Perhaps what most people do not realize is the fact that water is also being traded in other ways than the physical form. By importing water-intensive commodities, such as meat and meat products, the U.S. is being able to offset its agricultural water needs. These hidden economic and environmental benefits from the United States' point of view are the basic advantages associated with free trade (Krugman & Obstfeld, 2006). However, the costs and benefits of free trade, in terms of water loss and savings, have not been estimated.

Traditionally, agricultural water use has been estimated using the *coefficient approach*. This methodology involves the estimation of water demanded by crop by multiplying the number of units of production by the amount of water used for one unit (de Loë & Moraru, 2004; de Loë, 2005). In Canada, the Ontario Ministry of Agriculture and Food first used the coefficient approach in 1991, followed by Ecologistics Limited (a consulting firm based in Waterloo) in 1993 and by de Loë and his team to estimate Ontario's agricultural water use in 1992, 1996 and 2001. Statistics Canada has recently used this methodology to estimate national and provincial water use in livestock and irrigation (Statistics Canada, 2007b). However, no studies in Canada have been done to estimate how much water, embedded in agricultural commodities, is being exchanged with other nations through trade.

Recently Chapagain and Hoekstra (2003), scientists at the UNESCO – Institute of Water Education, introduced a new methodology to estimate water flows between nations.

The calculation is based on the estimation of virtual water content (VWC) of an agricultural commodity, a concept that had been formulated by a geography professor at King's College in London, J.A. Allan. By definition, virtual water is the amount of water present in agricultural products in terms of the amount of water used to produce it (Allan, 2003b). The methodological framework of the analysis is based on the fact that when there is a transfer of products or services through trade, there is little direct physical transfer of water (apart from the water content of the product). There is however a significant transfer of virtual water (Chapagain & Hoekstra, 2003). Thus, by multiplying trade volumes with the VWC, it is possible to estimate the amount of virtual water flow between nations.

This methodology will underpin this thesis, in order to determine the amount of water being traded between Canada and the United States in livestock and livestock products. The calculation will help to establish the implications to Canada's water resources due to trade liberalization brought forward by the free trade agreements.

1.3 Purpose and research question

The purpose of this research is twofold. First, it will assess the virtual water content of various types of livestock and livestock products and quantify the virtual water flows related to trade in livestock and its products between Canada and United States. Secondly, the study will examine the North American Free Trade Agreement (NAFTA) and evaluate its implications for Canadian water resources.

The virtual water concept is a new and emerging issue in the water research area and is yet to gain full recognition by scholars and scientists. This research will help establish a framework whereby further research can be conducted. The research findings will contribute to the field of agriculture, water management in agriculture and agricultural sustainability – specifically addressing the concepts of agricultural water management, efficiency and allocation, limitations and recommendations. It will also be applicable to the formulation of policy directives in the field of agriculture, land and water resources and will provide extensions for further research into the concept. It will contribute to an ecological economic critique of how markets often externalize environmental costs and how free trade, based on comparative advantage, fails to consider such costs in its calculations.

The following research question forms the basis of this research:

How much virtual water is being traded through livestock and livestock products between Canada and the United States and what implications does this trade have on Canadian water resources?

In order to answer the primary question, four secondary questions have been used:

1. *How has NAFTA affected Canada-U.S. trade relations?*
2. *How has the trade in livestock and livestock products changed from pre-to-post NAFTA?*
3. *What is the net balance of virtual water being traded between the two countries in the livestock sector?*
4. *What are the implications of the U.S.-Canada meat trade on water resources of Canada?*

1.4 Organization of the thesis

Following the introduction, Chapter 2 is a review of literature pertinent to this research. It is broken down into four main sections. The first section gives an overview of the conceptual framework of the thesis. The second section of the chapter introduces the Canadian agriculture and water scenario. This section help set the stage to understand the agricultural background related to livestock production. The water allocation and distribution in the different provinces are also highlighted with focus on two case study regions, Alberta and Ontario. The third section introduces the concept of virtual water. Here the evolution of the concept is discussed together with a critical analysis of the different school of thoughts supporting it. Finally, the NAFTA is discussed with critical analysis of the NAFTA-water debate. The position of virtual water in the NAFTA-water debate is also analyzed here.

Chapter 3 provides the methodological framework of the research. The framework is an explanation of how this research has been conducted. It highlights the virtual water concept as has been used in the research and outlines the research design, tools and research outcomes. The boundaries and limitations of the research are also highlighted in this chapter.

Chapter 4 is the research findings chapter. Here the results of the virtual water content and virtual water flow calculations are summarized. The results include those for Canada and the two case study areas: Alberta and Ontario. Graphs have been provided to make a better understanding of the outcome of the research.

Chapter 5 is the discussion chapter. It provides a summary of the research findings as is pertinent to the primary and secondary questions posed in the research and provides an discussion of the position of virtual water within the NAFTA framework.

Finally, Chapter 6 concludes by providing recommendations and further scope of research in the virtual water field.

2 Literature Review

This chapter explains both the conceptual framework of the research as well as the literature relevant to this research. It is broken down into various sections, which provide the background knowledge to answer the primary and secondary research questions. The conceptual framework provides a visual explanation of the research plan and explains how the research fits into the water management literature. The latter sections examine the agricultural and water background of Canada. This is followed by the explanation of the virtual water concept. Finally, the literature review ends with a review of the NAFTA provisions for water and the debate surrounding it.

2.1 Conceptual Framework

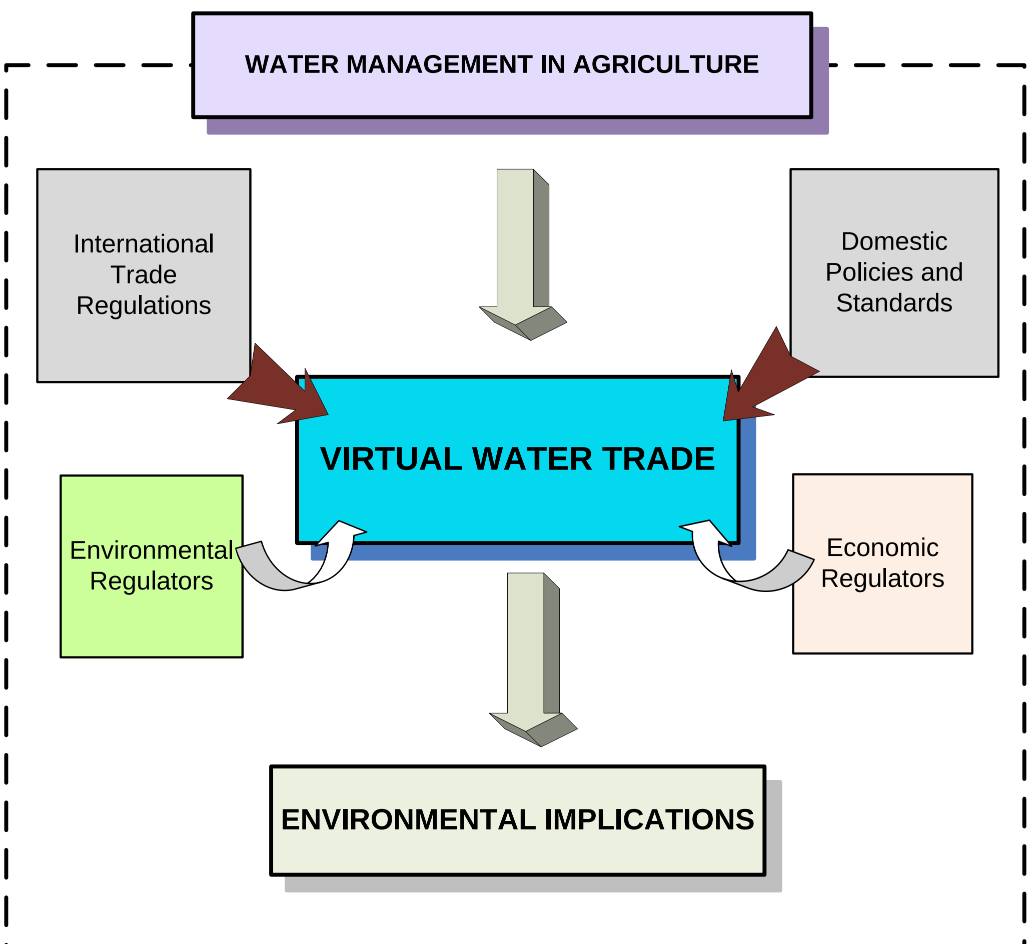
The conceptual framework is the foundation of the rest of the analysis. It will be used to highlight the key sources of explanation for the key questions outlined in the introduction. It will also be used as a checklist to ensure that the significance of as many factors as possible are evaluated. Figure 1 is a visual explanation of the conceptual framework and the relationship between key concepts and theories.

The foundation of the research is based on the broad umbrella concept of water management, specifically in agricultural production. Virtual water acts as the conceptual lens for the entire study and provides the driver for the subsequent research. International trade regulations and domestic policies act as a system of drivers in the trade of virtual water. Resource endowments and opportunities, e.g. environmental and economic regulators are influencing forces which determine the amount of water traded in the embedded form (virtual water). The ultimate goals of this research are to understand these concepts and to evaluate the amount of virtual water being traded and Canada’s implications on its water due to its free trade pact with the U.S.

The fundamental assumptions of this research are:

- Canada is bound by the obligations in NAFTA to grant unrestricted access to water-intensive agricultural production, specifically meat and meat products to U.S. markets.
- Virtual water has not yet gained recognition in the water management community, especially among policy makers and scientists.
- Virtual water and its trade is not accounted in the Canadian national water budgets.
- The virtual water calculation for Canada will assess Canada's impact on its water resources due to trade with the U.S.

Figure 1: Conceptual Framework of the research



2.2 Agriculture in Canada

2.2.1 Introduction

This section provides an overview of the Canadian agricultural systems. The first part provides a background of the different segments of the Canadian agri-food chain and highlights the contribution of the system to the whole economy. Since the livestock industry is the focus for this thesis, the latter sections will contain an overview of the livestock and meat industry and the production pattern changes since 1991. The section then concludes by providing an overview of the water resources available in Canada and the stress put on by agricultural activities.

2.2.2 Canadian Agri-food system

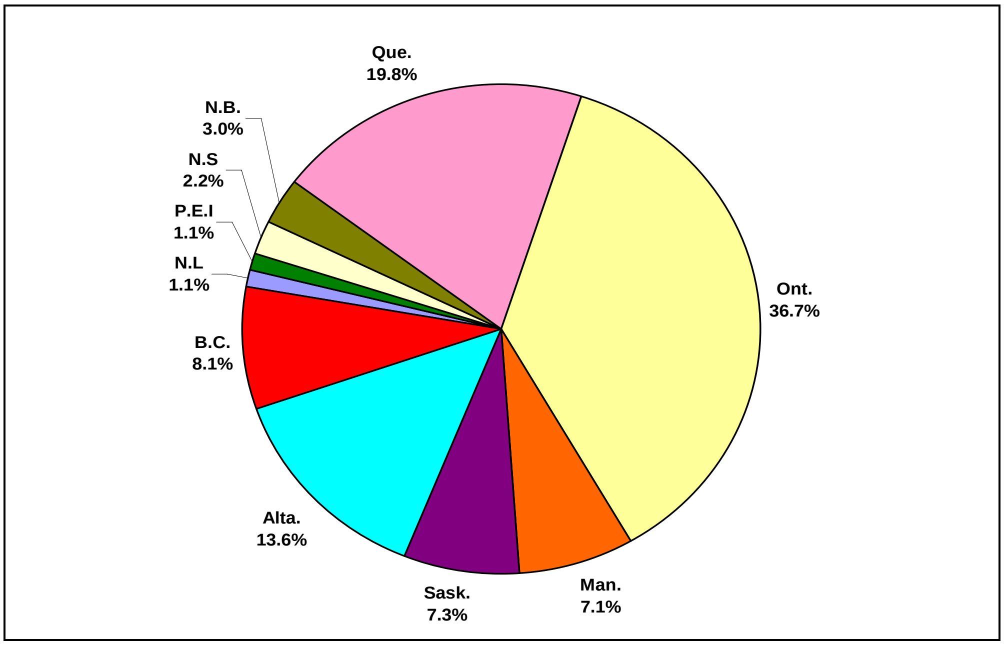
The agri-food system is a significant part of the Canadian economy. It is composed of all industries whose primary role is to produce food and agricultural products. It encompasses both primary agriculture and food processors. The food distribution sector is composed of all industries whose primary role is to directly provide and service the final consumer with food and agricultural products. It encompasses food retailers/wholesalers and foodservice establishments. Food processing (which includes beverage and tobacco processing) is the second largest contributor to manufacturing GDP in Canada, while food retail is the second largest consumer good expenditure category, and foodservice the third largest consumer service expenditure category (Agriculture and Agri-food Canada, 2006).

2.2.2.1 Economies of the Agri-Food System

GDP: In 2004, the Canadian agriculture and agri-food sector accounted for 8.1% of gross domestic product (GDP). Provincially, agriculture and food processing played the largest role in Prince Edward Island, claiming over a 10% share of the total provincial GDP, while Saskatchewan and Manitoba had a 7% share in 2004 (Statistics Canada, 2007c).

The relative size of the agriculture and agri-food sector is varied across Canada. From Figure 2 it can be seen that Ontario, Quebec and Alberta sector GDP accounted for 70% of the total provincial contribution to Canadian agriculture and agri-food sector GDP in 2004 (Agriculture and Agri-food Canada, 2006).

Figure 2: Provincial Contribution to Canadian Agriculture and Agri-Food Sector GDP, 2004



Source: Adapted from Agriculture and Agri-Food Canada, 2006

Food processing is the largest manufacturing industry in seven provinces. It is the second largest in Ontario and the third largest in British Columbia and New Brunswick (Agriculture and Agri-food Canada, 2003). In the Prairies, primary agriculture plays the more important role.

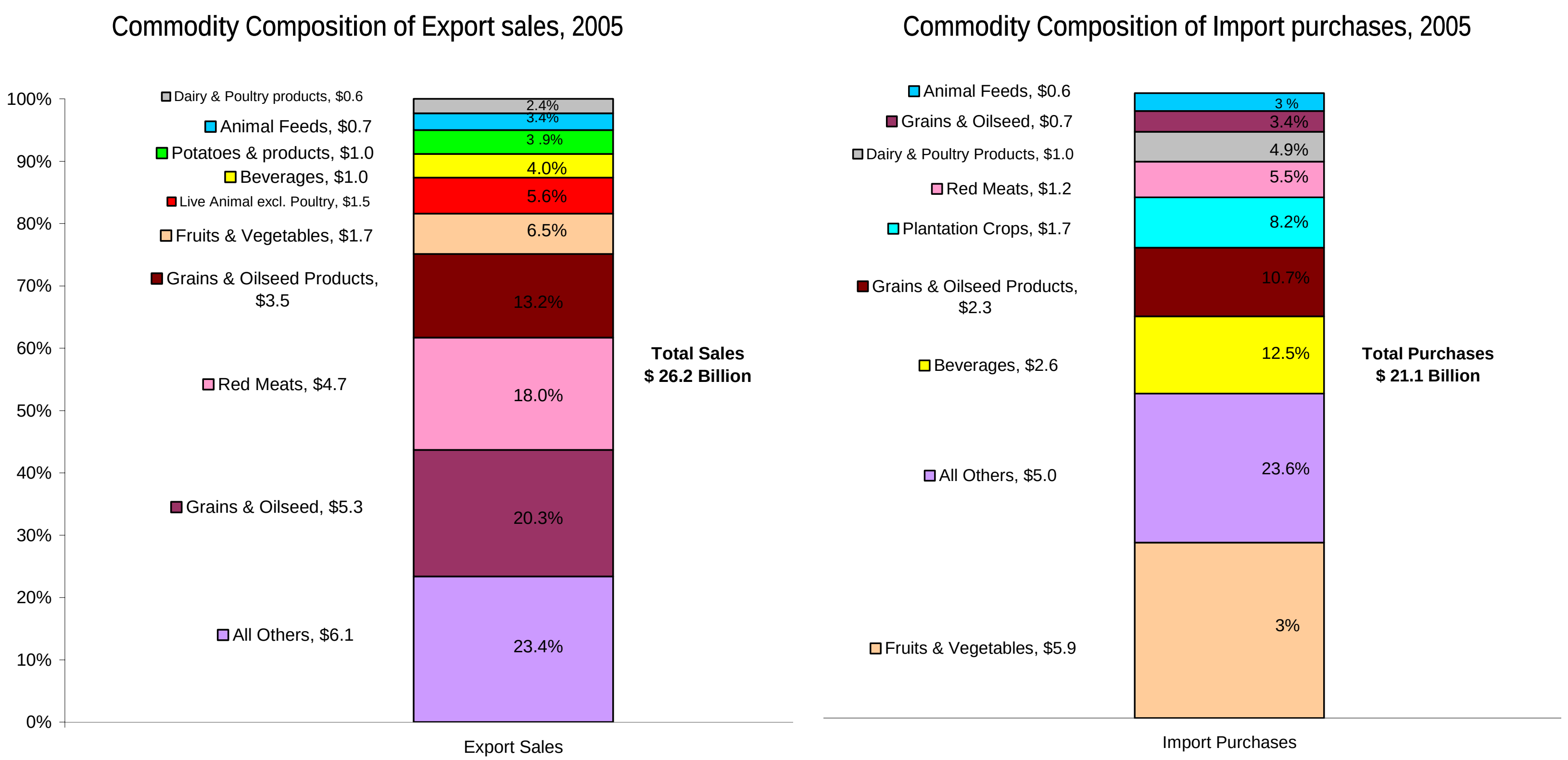
Employment: In 2004, the agriculture sector provided one in eight jobs, employed nearly 2.1 million persons and indirectly generated employment in other sectors (Agriculture and Agri-food Canada, 2003; Agriculture and Agri-food Canada, 2006; Statistics Canada, 2007a). In absolute terms, Ontario and Quebec have the largest number of people employed in the whole system. However, the system accounts for the largest shares of provincial employment in Prince Edward Island and Saskatchewan (around 20%) (Statistics Canada, 2007a).

International Trade: Since the 1970s Canadian agriculture and agri-food exports have commanded a 3% to 4% share of the world's total food exports (Statistics Canada, 2007a). Between 2001 and 2003, Canada saw its export share of agricultural commodities decline rapidly, mostly due to factors relating to unfavourable growing conditions, trade restrictions on meat and livestock due to Bovine Spongiform Encephalopathy (BSE), and a stronger Canadian dollar. In 2004, this trend was reversed and Canada's share represented 3.4%. According to Agriculture and Agri-Food Canada statistics (2006), Canada was the fifth largest exporter of agriculture and agri-food products in the world in 2004, after the EU, U.S., Brazil and Australia with exports valued at C$26.5 billion. It is also the fifth largest importer of agriculture and agri-food products with imports valued at C$20.4 billion.

The U.S. remains Canada's largest trading partner, accounting for over 60% of Canada's total agriculture and agri-food export sales in 2005 compared with a 40% share in 1990 (Statistics Canada, 2007a). This increase has been attributed by the implementation of NAFTA, which has created a free trade zone between the Canadian-U.S. markets. Details of the NAFTA provisions can be found in the later sections of this chapter.

Canada continues to export more bulk commodities and intermediate goods than consumer-oriented products. Grains and oilseeds are the largest export commodities accounting for one-third of the total value of agriculture and agri-food exports, followed by livestock and meat products. Consumer products, including tropical fruits and vegetables, as well as coffee, tea and other products unavailable from domestic production, dominate imports. Figure 3 below represents the commodity composition of export and import sales in 2005.

Figure 3 : **Commodity Composition of Export Sales and Import Purchases for Canada, 2005**



Source: adapted from Agriculture and Agri-food Canada, 2006

2.2.3 Canada's animal agriculture

Animal production plays an important role in Canadian agriculture. Currently it accounts for half the value in all Canadian agriculture production. For example, in 2006, total livestock and poultry receipts amounted to C$17.960 billion of the total cash receipts of C$37.014 billion derived from agriculture (Statistics Canada, 2007a). Canada has a huge surplus of cereal grains, which not only fulfils the needs for the domestic market but also for animal agriculture (Blair & Lister, 1994). A description of the various sub-sectors within the animal production system is given below (for definitions of different animal categories refer to Appendix 1).

2.2.3.1 Dairy sector

Canadian dairy producers supply two main markets: (1) the fluid milk market, which includes flavoured milks and creams; and (2) the industrial milk market, which uses milk to make products such as butter, cheese, yogurt, ice cream and milk powders (Agriculture and Agri-food Canada, 2005a). Canadian milk and dairy products are world-renowned for their quality and standard. Improved genetic stock, changes in breed representation in the dairy cattle population, improved feeding and management and health are all factors contributing to the increased production over the past few decades (Agriculture and Agri-food Canada, 2005a; Blair & Lister, 1994; Statistics Canada, 2006b; Statistics Canada, 2007a). A typical Canadian dairy farm has 66 cows. The main breeds of dairy cows are Holstein (comprising more than 93% of Canadian dairy herds), Ayrshire, Jersey, Brown Swiss, La Canadienne, Guernsey, and Milking Shorthorn. Some of the key statistical highlights from 2005, as indicated by Statistics Canada (2006b) were:

- In 2005, the total net farm receipts from dairy production were C$4.8 billion. The dairy industry ranks fourth in the Canadian agricultural sector following grains, red meats and horticulture.
- In 2005, Canada exported mainly cheeses (27.1%) followed by dairy spreads (18.0%) and ice cream (16.0%). The major markets for dairy products exports are the United

States (48.1%), and the European Union (12.9%), in particular the United Kingdom (12.1%).

2.2.3.2 Cattle and Beef sector

Cattle production is a key part of the Canadian agricultural sector. It consists of highly productive beef cattle breeds such as Hereford and Angus. These breeds are know for their hardiness, adaptability to the Canadian climate, and excellent foraging capability (Athwal, 2002). Others, such as the European breeds of Charolais and Simmental were introduced in the 1970s. These are later maturing, faster growing, and generally more heavily muscled breeds believed to be important in increasing the genetic base of the general herd (Canada Beef Export Federation, 2006).

The Canadian beef production system consists of three main types of operations: (1) cow/calf operations, (2) backgrounding operations, and (3) feedlot/finishing enterprises. According to Athwal (2002), cow-calf operations are enterprises where a cow herd is maintained and calves are raised and ultimately sold after weaning from the mother cows. The established practice of most cow/calf ranches in Canada is to breed their cows in June and July. Calves are born in March and April of the following year. The calves graze with their mothers on pastures and grasslands throughout the spring, summer, and fall seasons. The average weight of calves at weaning in the fall (October or November) is about 250 kilograms, but weights can range from 160 to 320 kilograms depending on age at weaning, the genetic background of the calf, and grass condition during the summer grazing season. In Western Canada the herd is usually fed barley-based rations while corn and barley is fed in Central and Eastern Canada (Canada Beef Export Federation, 2006). By definition, backgrounding is the process of feeding high forage (alfalfa hay and straw) feeds to increase the weight of smaller calves up to 350 kilograms (Canada Beef Export Federation, 2006). This process usually starts in fall and extends until spring, until the calf reaches its expected weight. This phase can occur either in the feedlot or on grass pasture. The final phase in beef production is the feedlot/finishing phase. A typical feedlot/finishing operation buys feeder animals from the backgrounding/stocker operation or cow/calf producer and puts the animals on a high-energy ration to increase in weight till they reach their slaughter weight (Athwal, 2002). The average live weight at slaughter for steers is about 630 kilograms, while the average weight for heifers is about 590 kilograms.

Some of the key statistical facts about the beef industry as highlighted by Canada Beef Export Federation (2006) and Canadian Cattlemen's Association (2007) are as follows:

- Farm cash receipts from the sale of cattle and calves in 2005 totalled C$6.4 billion or 17% of the total farm cash receipts.
- There are just over 90,000 farms reporting beef cows in Canada. Most beef cowherds (60%) are small to medium sized with less than 122 head. The average cowherd size is around 53 head.
- Total Canadian beef production was 1.6 billion kilograms in 2005, and Canadians consumed an estimated 1.0 billion kilograms of beef.

2.2.3.3 Swine sector

The Canadian swine production system consists of three main types of operations: (1) farrow-to-finish, (2) farrow-to-feeder, and (3) feeder-to-finish operations (AgraAbility Quarterly, 2006). Farrow-to-finish operators handle the pigs from birth to market, including breeding and farrowing the sows, as well as raising the pigs to a market weight of approximately 240 pounds (109 kg). The entire cycle of breeding, gestation, and raising piglets to market weight generally averages around ten to eleven months. A farrow-to-feeder (farrow-to-wean) farm raises the piglets to a weaning age, usually fifteen to seventeen days of age. The piglets are sold to a feeder-to-finish operation. This production system requires facilities for breeding, gestation, farrowing and, commonly, raising replacement gilts. Feeder-to-finish operations get the piglets at weaning age and raise them until the pigs reach market weight. This production system has the least varied types of facilities. According to Agriculture and Agri-food Canada (2005c) about 70% of processed meats in Canada, such as sausages or cold cuts, are made with pork. In 2005, 14.7 million hogs were recorded on approximately 13,000 farms. Farm cash receipts from the sale of slaughter hogs totalled C$3.9 billion, almost 11% of total farm receipts (Statistics Canada, 2007c).

2.2.3.4 Poultry sector

The production of chicken and turkey dominate the Canada's poultry industry. However, other less traditional birds such as ostriches, emus, rheas, ducks, geese and game birds such as pheasant, partridge, guinea fowl, quail and squab are also raised commercially in Canada. There are approximately 5,000 commercial poultry and egg producers in Canada (Chicken Farmers of Canada, 2007) and the business spans across various other stakeholders. According to Census of Agriculture 2006 (Statistics Canada, 2007a), there are 121 hatcheries, 140 feed manufacturers, 116 feed supplement suppliers and 42 drug suppliers all directly or indirectly related to the poultry sector. Canada's poultry production and processing sectors are highly efficient and mechanized. A producer can operate a unit of 50,000 broiler chickens, which, with seven lots per year, can provide 640 tonnes of meat annually, while the poultry processing plants are said to be able to slaughter and prepare 25,000 broiler chickens for market per hour (Statistics Canada, 2007e). In 2004, there were 2,787 regulated chicken producers and approximately 538 registered turkey producers in Canada. They produced poultry products (meat and egg) worth C$2.3 billion in 2005, contributing 6.2% of total cash receipts to farming operations (Statistics Canada, 2007c; Statistics Canada, 2007e).

2.2.3.5 Other livestock sectors

Apart from beef and pork, Canada's red meat and meat products industry includes sheep, lamb, venison and bison. According to Census of Agriculture 2006 (Statistics Canada, 2007a), in 2005, there were:

- approximately 12,000 farms in Canada carrying 980,800 sheep and lambs. Farm cash receipts for sheep and lamb in 2005 totalled C$112 million.
- about 2000 farms raising 162,000 head of venison. Elk are primarily farmed in the west and red deer in the eastern provinces. Fallow deer, white-tailed deer and other venison species are found throughout Canada.
- about 1900 farms in Canada farmed 230,000 bison. Bison production is primarily concentrated in the west at 85-90% of all production in Canada.

2.2.3.6 Geographical distribution of livestock

From the 1990s, Canadian farmers have been raising more cattle, hogs and poultry than ever before despite the biggest decline in the number of farms, according to the *Census of Agriculture 2001* (Statistics Canada, 2002). The 2006 census counted 229,373 farms in Canada on May 16, 2006, down almost 17% from 1996, but as the values in Table 1 shows, the farm size has been steadily increasing. The average farm size is now 295 hectares compared to 246 hectares in 1996 (Statistics Canada, 2007c). The increase in size reflects in part economies of scale associated with a change to more capital-intensive technologies.

Table 1: Average Farm size

Year	1986	1991	1996	2001	2006
Area in hectares	67,825,757	67,753,700	68,054,956	67,502,446	67,586,739
Farms reporting	293,089	280,043	276,548	246,923	229,373
Average area in hectares per farm reporting	231	242	246	273	295

Statistics Canada, 2007c

In July 2006, there were 10.1 million "animal units" in Canada. "Animal conversion units" is a concept that is used in regulations, codes of practice and municipal by-laws related to livestock production in order to create equivalence among different types of livestock, regardless of type, age or end use (Beaulieu & Bédard, 2003). In terms of animal units, beef cattle dominated the livestock sector, accounting for more than half (51.2%) of the total, compared with 47% in 1991. Meanwhile, dairy cattle accounted for only 13.5% in 2006, down from 21.4% in 1996. In 2006, hogs accounted for 28.4% of the total animal population and poultry (chicken and hens), 6.14%.

Table 2: Animal Conversion Units used to estimate animal population

Type of animal	1991			2006		
	# of animals	Conversion	%	# of animals	Conversion	%
Total beef cows	3,828,630	3828630	46.95	5,215,500	5215500	51.15
Total dairy cows	1,315,178	1749186.74	21.45	1,035,500	1377215	13.51
Total sheep and lambs	935,891	58961.133	0.72	1,156,200	72840.6	0.71
Total pigs	10,216,083	2043216.6	25.06	14,521,000	2904200	28.48
Total hens and chickens	94,872,875	474364.375	5.82	125,314,793	626573.965	6.15
Total	111,168,657	8,154,359	100	147,242,993	10,196,330	100

Notes: (Please see Appendix 2 or more details)

Conversion units: Beef cow: 1; Dairy cow: 1.33; Sheep and Lamb: 0.063; Pig: 0.2; Hen and chicken: 0.005

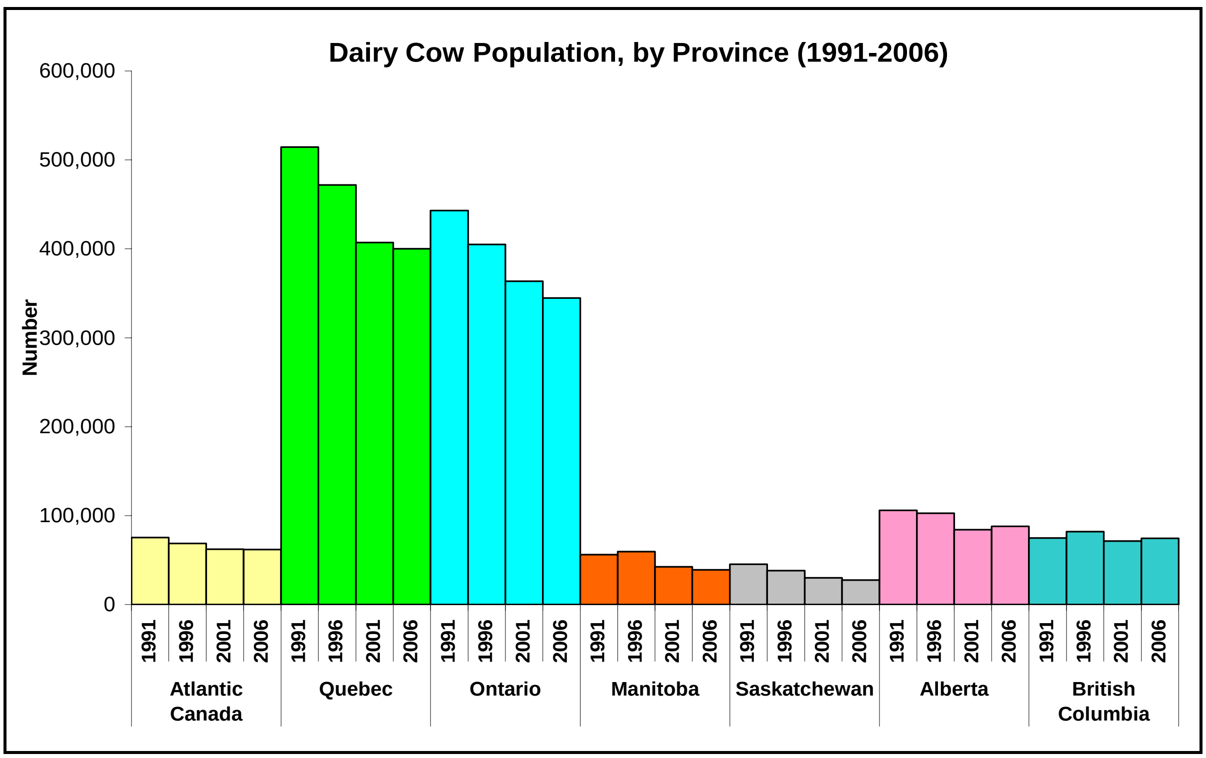
The section below highlights the trends in the livestock sector (by province) that have taken place over the last 15 years. This analysis will help establish the geographical distribution of the animal sector in Canada. A detailed table of the distribution can be found in Appendix 3.

2.2.3.6.1 Dairy Cow

The Canadian dairy cow industry is mainly concentrated in Ontario (33.2%) and Quebec (38.6%). In 2005, there were approximately 16,224 dairy farms in Canada, that produced a total of 74.92 million hectolitres of milk (Statistics Canada, 2007a).

By looking at figure 6 below (statistics in Appendix 3), it can seen that the dairy herd has been experiencing a gradual decrease since 1991 (approximately 21%). However, the average production per farm has increased significantly, by 68%, since 1995 (Statistics Canada, 2007a). This productive efficiency by the dairy industry in Canada has been achieved through better animal nutrition and continuing evaluation programs in search of hardier genetic breeds.

Figure 4: Trend in Dairy Cow Population, by province, 1991 - 2006



(Derived from values in Appendix 3)

2.2.3.6.2 Beef Cattle industry

The beef cattle industry has shown a steady increase in intensity over the last 15 years. The industry is predominantly based in Alberta and Saskatchewan. From 1991, Alberta's share in the beef cattle industry had increased by 32.5% in 2006, while shares in Saskatchewan increased by 50.9%. Figure 5 shows the trend in beef cattle population from the census year 1991 to 2006 in the different provinces.

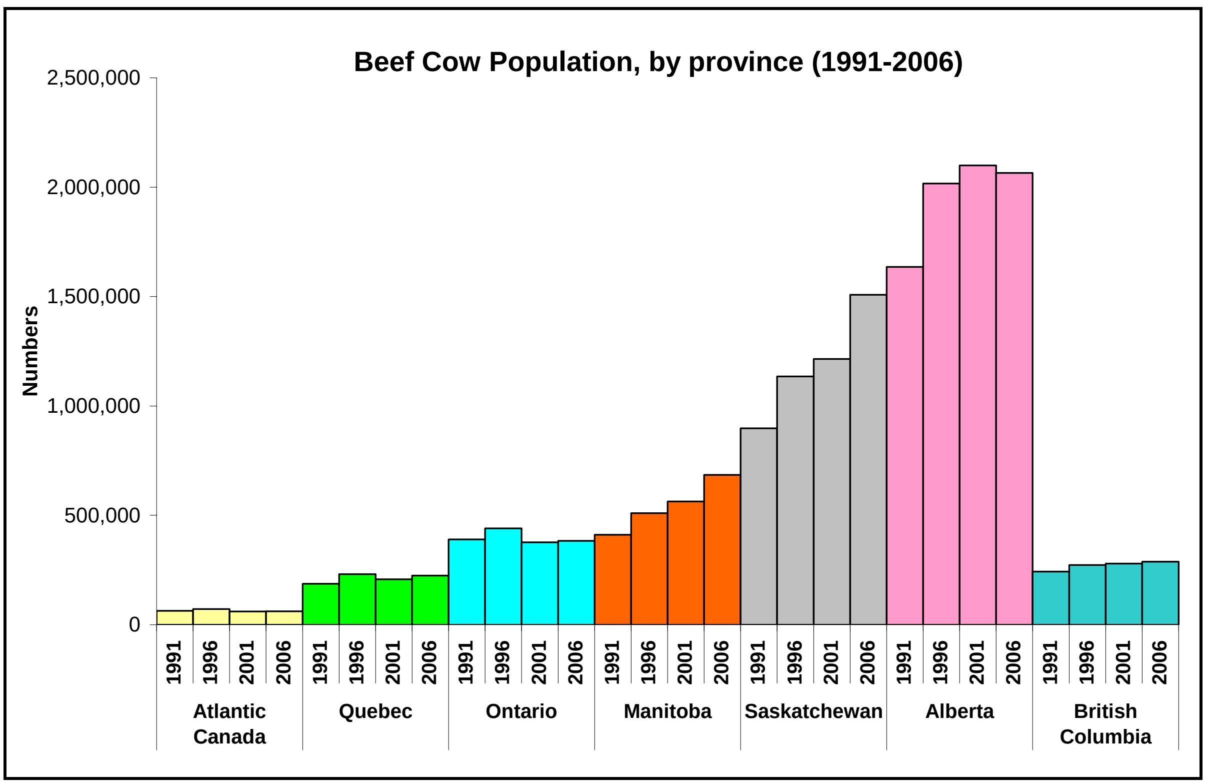
The beef cattle industry in Canada has gone through massive transformations in the past few years. The slight dip in the beef cattle production in Alberta in 2006 census had been due to the discovery of BSE (Bovine Spongiform Encephalopathy commonly known as "mad cow disease") in May 2003. According to Census of Agriculture 2006 (Statistics Canada, 2007a), beef farms declined by 10.2% to about 61,000 farms during in the intercensal period. Due to the closing of borders by the United States and 33 other countries to Canadian beef, operations were forced to retain their cattle hence causing an increase in herd sizes. On July 2006, Canadian farms held 413,100 more beef cows than in 2001, bringing the total to 5.2 million head. This increase in cows was mainly due to increases in non-reproductive cull cows, which were retained longer than usual because of record low prices, a continuing ban on exports for cattle over 30 months of age, and limited domestic slaughter capacity (Statistics Canada, 2007a). To counteract this increase, beef cow producers started decreasing the number of replacement heifers preferring to sell them for slaughter rather than add to their future production capacity. The beef industry in Canada is showing signs of improvement, indicated by the increase in exports since 2004.

2.2.3.6.3 Swine industry

Canada's main pork-producing provinces, Ontario, Quebec and Manitoba, continue to be the driving force behind the 42% increase in national pig numbers since 1991, to 14,521,000 (Figure 6). In Manitoba, the rapid expansion of the hog industry over the last 15 years have been attributed by the establishment of a large processing plant in Brandon and higher transportation cost to ship grain outside the province (Beaulieu & Bédard, 2003). According to Census of Agriculture 2006 (Statistics Canada, 2007a), there has been a trend towards production of larger hogs than pigs, since farms reporting pigs across Canada dropped 25.7% to 11,497 in 2006.

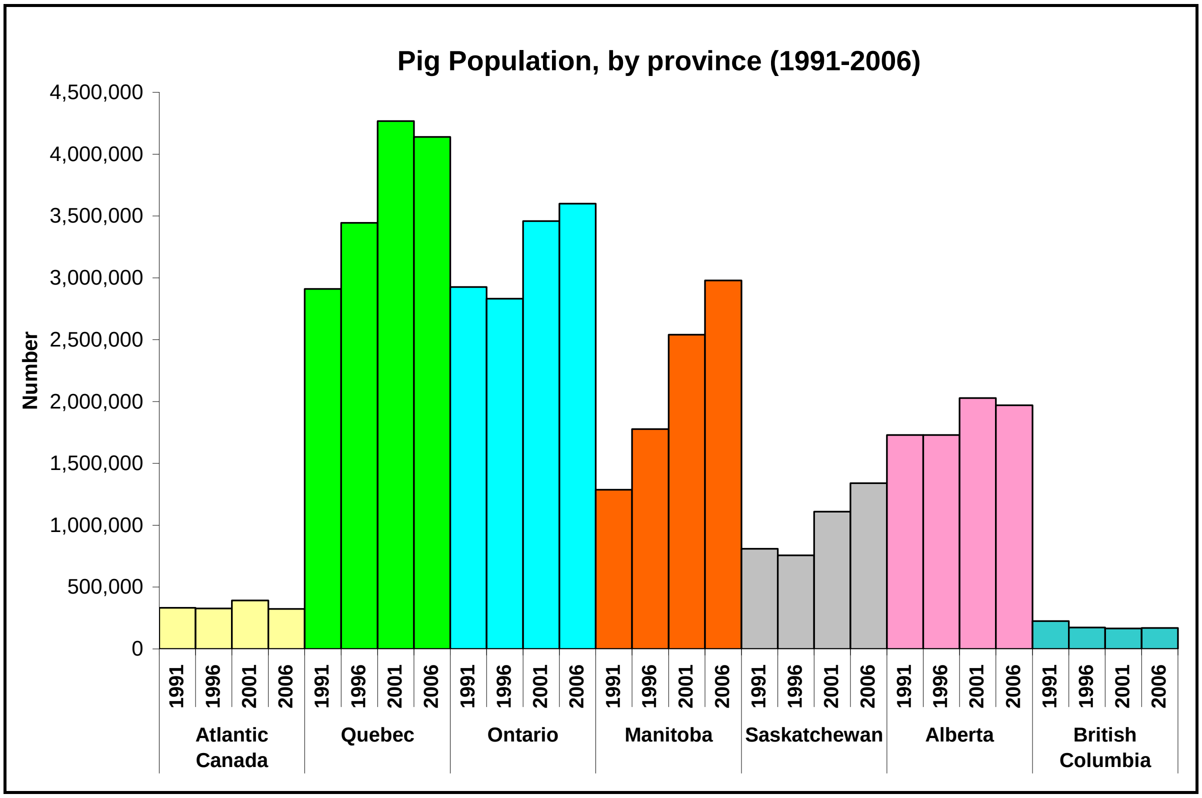
In recent times, many swine operations have chosen to specialize in a particular stage of the production cycle (Statistics Canada, 2007a). For instance, in the west, weaner pigs are exported to the United States to take advantage of lower feed costs and greater slaughter capacity south of the border (Alberta Agriculture and Food, 2007). Other factors that have attributed to changes in production cycles have been the incidence of circovirus in farms in Ontario and Quebec, higher grain prices, and the high Canadian dollar (Agriculture and Agri-food Canada, 2005b).

Figure 5: Trend in Beef Cow Population, by province, 1991-2006



(Derived from values in Appendix 3)

Figure 6: Trend in pig population, by province, 1991-2006

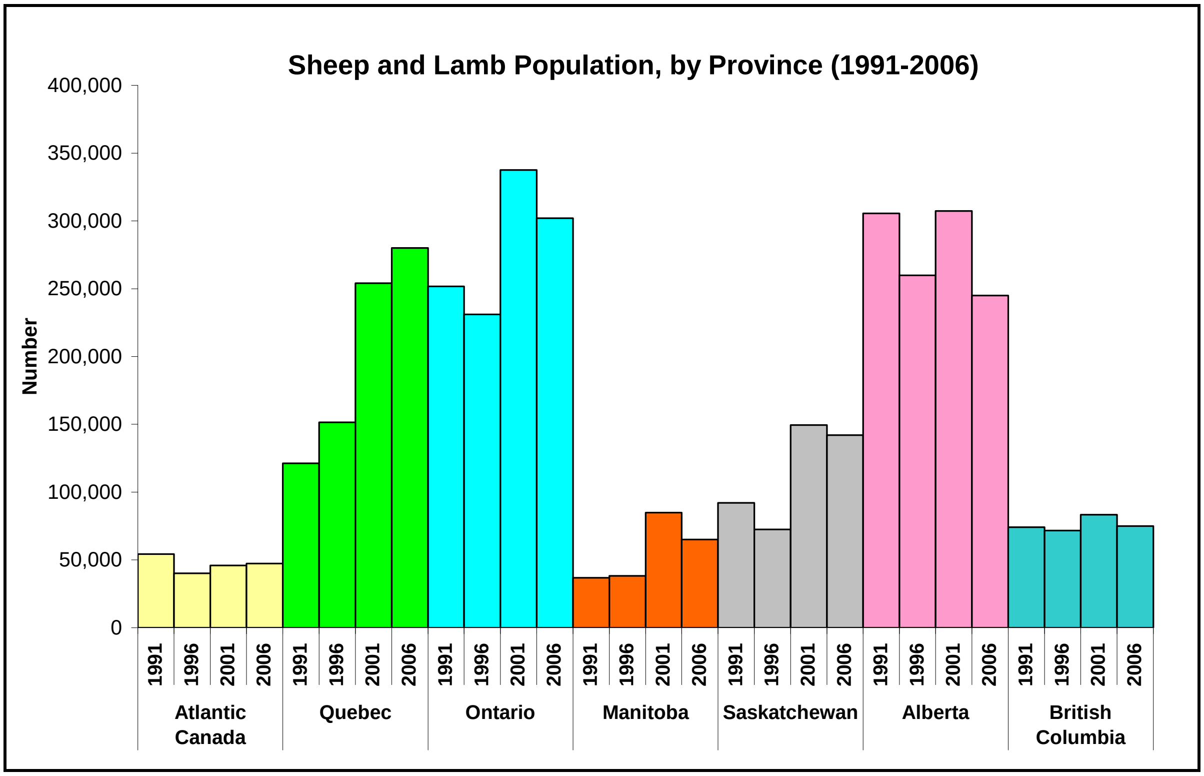


(Derived from values in Appendix 3)

2.2.3.6.4 Sheep and Lamb Industry

Before the 1970s, domestic supply of sheep and lamb were mostly met by imports from New Zealand, Australia and the United States. Since then Canada's level of self-sufficiency has approximately doubled to the 35 to 40 percent range (Kelly & Baldwin, 2001). Up until the 2001 census period, all provinces showed a significant increase in sheep and lamb production. The provinces with the largest increases in total numbers were Manitoba and Saskatchewan whose sheep and lamb population increased by more than 120 percent – significantly more than the rate of increase in any other province(Figure 7). Following the discovery of BSE in Alberta in 2003 and the subsequent closing of borders by the United States to all Canadian ruminant and ruminant products, including sheep, the industry has suffered tremendously, indicated by the lowered production capacities throughout the country.

Figure 7: Trend in Sheep and Lamb Population, by province, 1991-2006

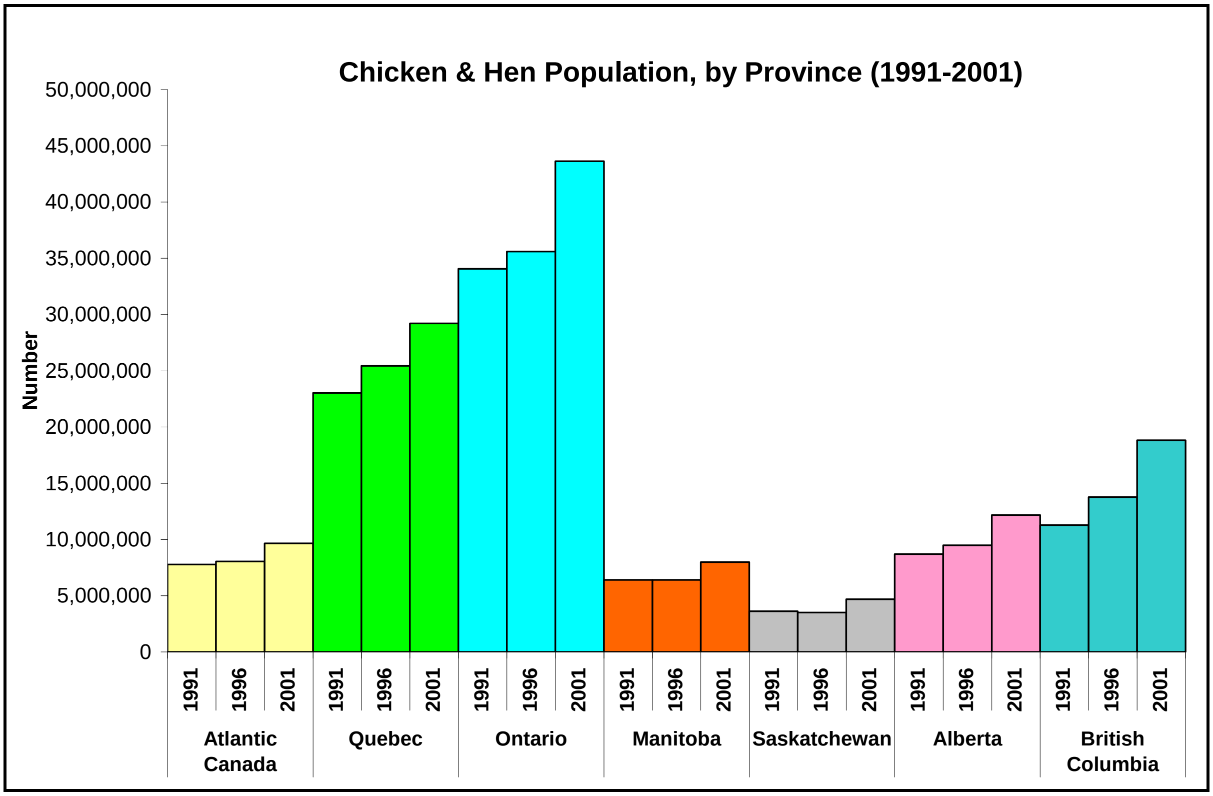


(Derived from values in Appendix 3)

2.2.3.6.5 Poultry industry

About 35% of the poultry population was located in Ontario in 2001, and the second largest in Quebec (23%). As in many other areas of the agricultural industry, increases in production efficiency in the rate of lay by hens, has enabled farmers to produce more with less. Fewer birds (25.9 million or 1.3% fewer than in 2001) are laying the nearly 13 dozen eggs consumed per Canadian every year (Statistics Canada, 2007a). Comparing the 1991 to 2001 provincial numbers for chicken and hens, the greatest increase has been in the provinces of Ontario, British Columbia and Quebec followed by smaller decreases in the Prairie and Maritime regions (Figure 8). The only province that has showed a declining trend in chicken and hen population has been PEI.

Figure 8: Trend in Chicken and Hen Population, by province, 1991-2001



(Derived from values in Appendix 3)

Note: Since the poultry population numbers by province were not available for 2006, the 1991 values have been compared to the 2001 numbers.

2.2.4 Policy changes to livestock trade under NAFTA

Since the implementation of the Canadian Free Trade Agreement (CUSFTA) and North American Free Trade Agreement (NAFTA), the Canadian agricultural trade with the U.S. has grown in size and importance. By eliminating numerous trade barriers, the agreements have allowed competitive market forces to play a more dominant role in determining agricultural trade flows between the two countries. In addition, NAFTA has established rules and institutions that mitigate potential trade frictions and promote foreign direct investment (Zahniser & Link, 2002). Although other factors such as weather conditions, population growth, technological competitiveness, market exchange rate and macroeconomic performance have all contributed to the increase in Canadian agricultural trade, there is nonetheless no denying that NAFTA has acted as a catalyst for increasing the agricultural trade between the two countries. The changes to policies in various livestock categories are as follows:

Cattle: The trade in cattle (especially breeding cattle) has been free of tariffs even before the CUSFTA and NAFTA. The major policy changes that have taken place after the onset of CUSFTA has been the elimination of Canadian tariffs on U.S. cattle. The tariff elimination was scheduled for the 9-year period that began on January 1, 1989 but was accelerated and completed by January 1, 1993. Canada has generally been a net importer of feeder cattle from the United States. Post-NAFTA agreements such as the Restricted Feeder Program (previously known as the North-West Pilot Program), which came into effect in 1999, had a major effect on U.S. feeder calf exports to Canada. Under this program, U.S. feeder calves could be shipped to selected Canadian feedlots without going through the usual quarantine procedures (Athwal, 2002; Zahniser & Link, 2002).

However, trade restriction due to the discovery of BSE in 2003 resulted in a dramatic decrease in Canada's trade in live cattle and beef. The United States together with 33 other countries closed their borders to Canadian cattle and beef. On July 18, 2005, the U.S. reopened its border to live cattle less than 30 months of age. All trade restrictions have been lifted since then.

Beef: Canada's trade in beef has flourished with the help of low tariff rates prior to the CUSFTA and the consequent exemption of the U.S and Mexico from its Meat Import Law. However, BSE had affected beef trade from 2003-2005, when beef exports were allowed mainly in the form of boneless beef cuts and some offal.

Dairy: Canada has a set of import quotas and licensing requirements to protect its domestic dairy supply management system, although most tariffs on U.S. dairy products have been eliminated under the two agreements.

Hogs: Canada did not impose tariffs (with the exception of health restrictions) on hog imports even before the signing of the CUSFTA, but analysts believe that the two agreements have indirectly increased hog trade to the U.S. by clearing the way for investment in the hog industry (Athwal, 2002; Haley, 2005). The major restructuring of the Canadian hog industry occurred because of policy changes in 1995. The Canadian government decided to reduce its subsidies to agriculture as part of the WTO subsidy reduction commitment (Haley, 2005), by repealing the Western Grain Transportation Act (WGTA). This repeal increased the cost of transportation of grains to eastern provinces from the western Prairie Provinces and hence created the incentive for raising livestock there. These policy changes in Canada had resulted in a supply of hogs in excess of Canadian slaughter capacity. However, structural changes in the U.S. around the same time mitigated the effect by allowing hogs to be imported from Canada for slaughtering purposes.

Pork: Even before the signing of the CUSFTA and NAFTA, pork trade between the two nations were relatively free of trade barriers, and the Canadian duties on U.S. pork trade was phased out by January 1, 1993.

Poultry: Prior to NAFTA, Canada had poultry production quotas and import limitations. The import quota for broilers was set at 6.3 percent of the previous year's broiler production, and at 2 percent of the current year's expected production for turkeys. Under CUSFTA and eventually NAFTA, the global quota allocations were increased to 7.5 percent for broilers and 3.5 percent for turkeys (Agriculture and Agri-food Canada, 2007; Goodloe, 1990; Zahniser & Link, 2002). In 1995, Canada signed the World Trade Organization (WTO) Agreement on Agriculture, whereby it became obligatory for Canada to convert its existing agricultural quantitative import controls to a system of tariff rate quota’s (TRQs). TRQs determine the quantity and the tariff at which a specific agricultural product is imported into a country. Because of the expansion of import quotas, imports from the United States have increased tremendously.

2.2.5 Water: availability and use

According to the Atlas of Canada (Natural Resources Canada, 2004), approximately 7.6% of Canada's land area is covered by freshwater in rivers and lakes making Canada fourth among the league of water-rich nations, after Brazil (18%), China (9%), and the United States (8%). The table below ranks the different Canadian provinces according the freshwater surface area.

Table 3: Canadian Provinces and Territories Ranked by their Freshwater Surface Area

Provinces /Territories	Total Area (land + water) (km²)	Freshwater Area (km²)	% of Jurisdiction Covered by Freshwater	% of Total Canadian Freshwater Area
Quebec	1 542 056	176 928	11.5	19.9
Northwest Territories	1 346 106	163 021	12.1	18.3
Ontario	1 076 395	158 654	14.7	17.8
Nunavut	2 093 190	157 077	7.5	17.5
Manitoba	647 797	94 241	14.5	10.6
Saskatchewan	651 036	59 366	9.1	6.7
Newfoundland and Labrador	405 212	31 340	7.7	3.5
British Columbia	944 735	19 549	2.1	2.2
Alberta	661 848	19 531	2.9	2.2
Yukon	482 443	8 052	1.7	0.9
Nova Scotia	55 284	1 946	3.5	0.2
New Brunswick	72 908	1 458	2	0.2
Prince Edward Island	5 660		0	Less than 0.1
Canada	9 984 670	891 163	8.9	100

Source: (Natural Resources Canada, 2004)

FAO's (2002) *AQUASTAT Database Query* reports that the total volume of renewable water resources available in Canada is 2902 km^3/yr, of which 2892 km^3 is surface water and 370 km^3 is groundwater. Data for the different provinces were not available, however, AMEC Earth and Environmental (2007) reports that the total volume of freshwater originating in Alberta (Water originating in Alberta = Total Outflow - Total Inflow) is approximately 56.1 km^3 per year.

From Table 3, it can be see that there is wide spatial variability in water supplies. The dry and arid regions of southern Prairies and the interior of British Columbia suffer from severe moisture deficits and rely heavily on irrigated water. According to a study conducted by Statistics Canada, Alberta had the greatest share of irrigation water use with 2,900,000 thousand m^3, followed by British Columbia and Saskatchewan in 2001 (Table 4). The three westernmost provinces constituted 95.9% of total water used for irrigation in 2001(Statistics Canada, 2007b).

Table 4: Total Irrigation Water Use by Province

Province	Irrigation Water Use (1000 m3)	
	Total	%
Canada	4,424,600	100.00
Newfoundland and Labrador	200	0.00
Prince Edward Island	1,400	0.03
Nova Scotia	5,400	0.12
New Brunswick	1,600	0.04
Quebec	49,000	1.11
Ontario	92,000	2.08
Manitoba	30,000	0.68
Saskatchewan	500,000	11.30
Alberta	2,900,000	65.54
British Columbia	845,000	19.10

Source: (Statistics Canada, 2007b)

Water for irrigation in Canada is supplied from both surface and groundwater sources, although the relative distribution of usage is dependant on place and time of the year. Table 5 below gives a summary of how the provinces meet their water demands.

Table 5: Water demand and sources in different provinces

Province/ Region	Water demand and sources
British Columbia	- Surface water supplies 82% of municipal, domestic and rural water while the rest 12% is fulfilled by ground water sources - 2% of irrigated land uses ground water as water source. For the Fraser Valley, south Okanogan Valley, and parts of the Kootenays, ground water is the sole source for irrigation. These are also the primary agricultural land in B.C.
Alberta	- Irrigation, the largest consumer of water in the province, uses 71% of the surface water resources and 1% of water from underground aquifers. - Most of the irrigated land (approximately 75%), is located in 13 irrigation districts, where water is provided by 7400 km of canals and pipelines and other large scale water storage infrastructure.

Saskatchewan	- Irrigation accounts for 30% of total surface water use and only 1% of ground water use. - Most of the provinces water demands are in the south but water resources are located in the north and southwest. There is also concerns of poor water quality and declining water tables
Manitoba	- Manitoba has a good supply of groundwater, in quality and quantity. - Water demands are met by a combination of surface and ground water sources. The province withdraws approximately 20% of all its water from aquifers, 48% of which is used for irrigation.
Central Canada	- Water demand in Ontario and Quebec are met through a combination of surface and groundwater sources, although, there is high variability in quantity and quality of water throughout the region - Almost 98% of water needs for municipal, industrial, rural, agricultural and thermal power generation are met by surface water sources. - The rest 2% is met through groundwater supplies. However, the amount used accounts for more than 40% of all groundwater used in the country.
Atlantic Provinces	- Atlantic Provinces have the highest levels of runoff, but 50% or more (100% in P.E.I) of the people rely on groundwater sources. - Little or no irrigation is carried in the region, due to moist climatic conditions.

Source: (de Loë, R. C. & Moraru, L.C., 2004; Statistics Canada, 2007b)

Water in livestock production

In livestock production, water is mainly used for drinking, to clean facilities, sanitize equipment, and dilute manure (Coote & Gregorich, 2000). From an animal's physiological perspective, water constitutes 50 to 80 percent of the live weight of an animal (Alberta Agriculture, Food and Rural Development, 2005) and is very important for its growth and maintenance of body tissues, reproduction, and lactation. An animal can survive a loss of most of its fat and protein, but the loss of 10 per cent of its body water (through expired air, milk, urine, and feces, and by evaporation from the skin) can be fatal (Alberta Agriculture, Food and Rural Development, 2005). How much an animal drinks depends on the species, physiological conditions and environmental factors (Ministry of Agriculture and Lands B.C., 2006).

As is evident from the previous section, the livestock industry has been expanding rapidly in western Canada:

- From 1991, Alberta's share in the beef cattle industry had increased by 32.5% in 2006, while shares in Saskatchewan increased by 50.9%.
- Manitoba's hog production has more than doubled from the 1990s
- Manitoba and Saskatchewan's sheep and lamb population increased by more than 120 percent from 1970s.

This expansion has come with the growth of many intensive livestock operations (ILOs, large number of cattle, swine or poultry concentrated in a small area). According to the Alberta Agriculture, Food and Rural Development (Coote & Gregorich, 2000), 1.5- 3.0 litres/second of water needs to be pumped annually to meet the demand for a 5000-20000 steers during peak times in ILOs. This puts significant demands on water resources in these already stressed semi-arid regions.

2.2.6 Conclusion

This section provided an overview of the agricultural sector in Canada. Agriculture plays an important role in the Canadian economy. In 2006, the total cash receipts from this industry alone were C$34.014 billion, of which the livestock and poultry industry contributed approximately C$18 billion. Although there has been a decline in the number of farms over the last 30 years, the farm size has been steadily increasing reflecting in part economies of scale associated with a change to more capital-intensive technologies. Higher efficiency is causing farms to produce more with less. Provinces are moving towards specializing in one type of the animal, due mainly to structural reforms under NAFTA.

However, expansion of the livestock sector has been persistent in the semi-arid regions of the country such as Alberta, Manitoba and Saskatchewan. These places usually suffer from severe moisture deficits in the summer months and have to rely on irrigated water to meet agricultural needs. The unequal distribution of water availability and water needs need to be assessed by water managers, in order to see if the benefits of agriculture outweigh the cost to the environment.

2.3 *Virtual Water*

2.3.1 Introduction

This section introduces the concept of virtual water, which will act as the larger informing theory of the research. At first, the evolution of the concept is examined. Then the various worldviews surrounding the virtual water paradigm are highlighted together with their policy implications. The concept is also discussed from various international trade theory perspectives and finally the critics from the scientific community is depicted.

2.3.2 The Concept

The term "virtual water" was introduced in 1993 by Allan to indicate the amount of water made available in the global system through agricultural commodity trade (Allan, 1997; Allan, 1998). Allan interpreted the amount of water present in agricultural products in terms of the amount of water used to produce it (Allan, 2003a; Allan, 2003b). The concept was introduced as a powerful explanatory tool as to how the water deficient Middle East and North African (MENA) economies ameliorate water scarcity problems (Allan, 1997). The uniqueness of the virtual water concept lies on the fact that it focused not on the trade of water itself, but on the trade of water embedded within goods and commodities.

Unlike the terms such as "embedded water", developed by Allan in 1993 (Allan, 2003b) or "food, water and trade nexus", developed by McCalla in 1997 (Allan, 2003b), the virtual water terminology had gained acceptance rapidly in the water management community. Most recently (March 2008), Allan had been named the 2008 Stockholm Water Prize Laureate for pioneering the concept of virtual water as a key concept "in understanding and communication of water issues and how they are linked to agriculture, climate change, economics and politics" (SIWI, 2008).

The definition of the term has evolved over the years and authors of various scientific communities have adapted the concept to accommodate it in their field of work. Hoekstra (2003) for instance agrees with Allan's definition of virtual water as the water used in the production process of an agricultural or industrial product, but extends the concept "by including the water applied in the use and waste stages of the product" (Hoekstra, 2003: 14). Hoekstra also states that in order to quantify the virtual content of a product, two approaches can be held, one from a producer perspective, the other from that of the user. From a producer's perspective, "the virtual water content is defined as the volume of water that was in reality used to produce the product. This will depend on the production conditions, including place and time of production and water use efficiency" (Hoekstra, 2003: 13). From a user's perspective, "the virtual water content is defined as the amount of water that would have been required to produce the product at the place where the product is needed" (Hoekstra, 2003: 13). Virtual water can be used in the calculation of "water footprint" (Hoekstra & Chapagain, 2007) which is analogous to the ecological footprint developed by Wackernagel and Rees in 1996. The "water footprint" is defined as the sum of domestic water use in all production processes and net virtual water imports. According to Hoekstra and Chapagain (2007), the virtual water content of a product tells something about the environmental impact of consuming this product. The water footprint can be a strong tool to show people their impact on the natural resources. Awareness of one's individual water footprint could stimulate a more careful use of water.

VW has both intensive and extensive features (Weber, 1904, 1917 in Allan, 2003b). According to Allan (2003b: 111), it is intensive as it links both "freshwater and soil water in the crop production process". It is extensive because it links "water, food and availability of these commodities across national economies so that consumers as well as producers are considered".

Blue, Green, Brown and Virtual Water

How is virtual water different from the other forms of water that are commonly indicated in the scientific community? According to popular geological beliefs, water moves through the hydrological cycle in different forms, known as blue, green and brown water (Allan, 1997; Falkenmark & Rockstrom, 2004). Most of the water that we can usually quantify and manage is called the blue water. The blue water is the visible liquid water flow moving above and below the ground as surface and sub-surface runoff (Falkenmark & Rockstrom, 2004). This water ends up in streams, lakes, and groundwater and is said to be economically more viable than green water. The green water component in the hydrological cycle is the water in biological systems that supports natural vegetation and crops (Allan, 2000) and which is evapotranspired into the atmosphere. Green water is impossible to monitor and usually ignored by resource scientists and by economists as well as by engineers and politicians. Brown water, on the other hand, is the water found in the soil profiles and available for use by vegetation and crops (Falkenmark, 2004). Blue water falls under the category of 'evident' (Allan, 2000) water, or water of which users are aware. Green and brown water are 'invisible' or 'non-evident' (Allan, 2000) water.

All these three water components of the hydrologic cycle contribute to the growth and production of agricultural commodities. The actual volume of water used to grow these commodities is not usually contained within these products. The virtual water calculation does not make a clear distinction in the three types of water but it helps to realize, through its methodology, that both 'evident' and 'non-evident' water is needed to produce different agricultural goods and services. The precise volume of these types of water, however, depends on the climatic conditions and agricultural practice of the place of production. Hoekstra and Chapagain (2007: Appendix X1X) have defined the virtual-water content of a product (a commodity, good or service) as "the volume of freshwater used to produce the product, measured at the place where the product was actually produced". Perhaps another component, which is not considered in the production process of agricultural products, is grey water. The 'grey' virtual-water content of a product is the volume of water that becomes polluted during the production process. This has been highlighted in most of Hoekstra's studies (2003, Hoekstra and Chapagain 2007) when evaluating the total virtual water content of a commodity. However, for the purpose of this research this category of water has not been considered (for details see 3.2.1).

2.3.2.1 The different 'visions' of virtual water trade/transfer

When the term "virtual water trade" was introduced in 2002, it received criticisms from several economists claiming that the term is "misleading, because real things are traded, not virtual things" (Hoekstra & Chapagain, 2008, pp. 20). Since then the authors have used the term "virtual water transfer" to avoid confusion and maintain neutrality. In this research, “virtual water trade” and “virtual water transfer” have been used interchangeably, to mean a more physical bearing rather than having an economic connotation.

A few of the important perspectives and visions of virtual water trade highlighted by Allan (1998; 2003) and supported by Hoekstra (2003) and Wichelns (2004) are indicated below:

- *The strategic vision for food security:* The trade of virtual water is strategic and “effective” (Allan, 2003a: 111) in solving regional deficits of water. Nations export products in which they have a comparative advantage in production, while import product in which they have a comparative disadvantage. Politically, virtual water is silent, enabling political leaders to avoid confronting economic problems associated with water deficiency. “Virtual water provides a political solution at the same time as solving an economic problem… It prevents water crises from becoming water wars” (Allan, 2003a: 546).
- *The economic vision*: Virtual water transfer between nations can be an instrument to increase ‘global water use efficiency’ (Allan, 1997); to achieve water security in water-poor regions of the world and to alleviate the constraints on environment by using best-suited production sites. “Virtual water trade from a nation where water productivity is relatively high to a nation where water productivity is relatively low implies that globally *real water savings* are made” (Hoekstra, 2003: 14).
- *The liberal vision*: The role of virtual water in solving food deficits is global in reach and immensely more powerful than any policies deployed in managing water (Allan, 2003a). Importing countries need not be water poor or water short to be receiver of this virtual flow. Virtual water trade opens the national water market and helps the channelling of water for more profitable use (Renault, 2003) .

The above perspectives of virtual water can be seen as the supply-driven visions that focus on the movement of water embedded in food from production sites to consumption areas. Renault (2003) on the other hand, looks at virtual water from a *consumption vision*. This vision considers that the amount of water required for food production is not only driven by population but also by food habits, i.e. diets, and so the debate on water for food should also be placed in the consumption level. In a study conducted by Renault (2003), it was found that a survival diet would require 1 m^3 of water/capita/day, whereas a diet consisting of high animal protein intake would need 10 m^3 of water/capita/day. Therefore, food habits of a country have real impacts on water resources. If water for food is to be tackled, then both supply and demand side of the virtual water trade needs to be realized.

2.3.2.2 Virtual water and the policy dimension

Many authors suggest that a water crisis is imminent in many parts of the world (Ramirez-Vallejo and Rogers, 2006). As a result, we need to improve water management, and focus on reducing demand and improving the efficiency of water use. Significant savings can be made in water use if the concept of virtual water is incorporated into water allocations, but since this is a relatively new area of research, some basic research is required to make sure that the results are credible and capable of influencing policy and the governance of water.

The virtual water concept is a tool that can help in developing alternatives in water, food and environmental policies. Accounting of virtual water as an externality allows a wider spectrum of alternative and effective policies. Externality is a situation in which the private costs or benefits to the producers or purchasers of a good or service differs from the total social costs or benefits entailed in its production and consumption. Many negative externalities, also called “external costs” or “external diseconomies”, are related to the environmental consequences of production and use (for details see Daly & Cobb, 1994).

The VW concept is also a practical policy tool that can be extended to detailed analysis of water resources management, environmental policies, irrigation policy and international trade issues (Turton, 2000). Until now, many of these policy issues have been solved empirically by common sense food policies and strategies in many semi-arid Middle Eastern countries. Some of these countries like Israel and Jordan have made policy choices to reduce or abandon exports or local production of water intensive crops and replace them by imports or higher return crops to allow optimization of water use. These are the conscious choices related to what might appear as a common sense strategy.

2.3.2.3 Virtual water and International trade theories

According to Allan (2003), virtual water is a descendant of the concept of comparative advantage, a term coined by David Ricardo (1846). The Ricardian model is the simplest model in international trade theory that shows how differences between countries give rise to trade and gains from trade (Krugman & Obstfeld, 2006). Comparative advantage is a fundamental component of international trade theory. Nations can gain from trade if they concentrate or specialize in the production of goods and services for which they have a comparative advantage, while importing goods and services for which they have a comparative disadvantage. However, the proposition of Allan has been subjected to varied interpretations among other economists.

Hakimian (2003) reinterprets factor endowments and comparative advantage theory suggesting that the virtual water hypothesis is rooted in the Heckscher-Ohlin school of thought. The H-O theory is an extension of the Ricardian concept of comparative advantage and consists of two essential premises: (i) that countries vary from each other in terms of their productive resources (inputs such as labour, capital and natural resources); and (ii) that goods are produced using different proportions of those resources (Hakimian, 2003). Thus, countries tend to export goods that are intensive in the factors with which they are abundantly supplied (Krugman & Obstfeld, 2006). The trade in commodities is an indirect way of trade in factors of production, i.e. water in the case of food. Although the H-O model is extremely useful to explain major patterns of trade, it is however, not the only factor.

According to Wichelns (2004), the virtual water metaphor addresses the water endowment of a country, but it does not address the technology of production or the opportunity costs of water and other limited resources. Water-short nations can exercise absolute advantage over water-rich countries if they produce goods at a lower cost, even if water is a key input. The absolute advantage does not imply that the water-short nation should export both of the goods. Wichelns (2004: 52) goes on to suggest that the virtual water metaphor cannot be used to "determine optimal production and trading strategies." It is however very useful to first attract policy makers who will then consider opportunity cost and comparative advantages and select appropriate strategies for policy and trade.

Kumar and Singh (2005) on the other hand advocate changing the rationale of virtual water from "water use efficiency" and "distribution of scarcity" to "land use efficiency". They argue that "productivity potential of water" should be the innate water management goal if virtual water trade is to be made an operational policy tool for addressing water deficits. If food security is analyzed from a purely water resources perspective, then it would be a distorted view of the food security scenario (Ioris, 2004; Kumar & Singh, 2005). National policies on food security should take into account the access to arable land and analyze the water in the soil profile (green water). This analysis would be an important determinant of effective water availability for food production.

2.3.2.4 Critics of the virtual water concept

The concept of 'virtual water' has been contested at various levels. Merrett (2003a; 2003b) and Ioris (2004) have been the forerunners in this regard and have provided critiques of the concept from philosophical and economist perspectives and concluded that the concept is scientifically redundant and should be abandoned.

If 'virtual' means something "parallel to or imitative of a real-life entity or process" (Merrett, 2003b: 104), then virtual water is not "virtual" is any sense. There is a linguistic flaw in the entire virtual water thesis. Merrett (2003b: 104) argues that if virtual water, by definition, is nothing more than the water needed to produce agricultural commodities and is real then the term is wholly redundant and "inherently misleading". Terms like "crop water requirement" are already present in literature, which are similar to the virtual water concept. He recommends that the scientific community should be focusing more on fine-tuning its existing language, if it is to make any advancement, instead of harbouring vague and misleading concepts. "Social science, if it is constructed on a metaphor, is built on sand" (Merrett, 2003a: 541). Metaphors cannot be used to give valid scientific arguments.

According to Ioris (2004), the concept coincides with the common western utilitarian way of approaching a problem and ignores the complex matrix of socio-environmental problems related to local interests, forces of production and environmental regulators. Virtual water "only addresses the consequences of the water problem, not the structural causes of agricultural inadequacies and food shortages" (Ioris, 2004: 119). Merrett also raises similar concerns by stating that in agriculture, water is one of the many factors affecting its productivity and outputs. The concept lacks a “more-rounded” (Merrett, 2003b: 104) visioning. Ioris (2004) points out that trade in virtual water causes an uneven balance of power and opportunities between nations by firstly making the receiving country dependent upon the international market (which is highly influenced by subsidies in the northern countries). Secondly, it forces economies to maximize the utilization of scarce resources and cause environmental degradations, and lastly, it hampers the possibility of growth in appropriate local technology and infrastructure.

As a counter argument to these criticisms, Allan (Allan, 2003b) articulates that virtual water is an extremely useful metaphor given the fact that it is actually “real water” and that the trade of virtual water is actually the ‘trade of food’. Numerous terms, such as comparative advantage, political economy and shadow pricing have made economic theory very influential. What makes all these concept so interesting is the mere fact that it captures a theory in a word or a phrase enabling “communication, especially across disciplinary divides ... [to] be immensely facilitated” (Allan, 2003b: 111). Thus, considering the intensive and extensive nature of the virtual water concept, the ‘import of food’ can be looked at as the ‘import of virtual water’ or water embedded in commodities from water rich to water deficient economies. Instead of going in-depth in explaining the complexity associated with economic systems, it provides “an analytical perspective on how economies achieve water security” (Allan, 2003b: 111).

2.3.3 Conclusion

The concept of virtual water has varied interpretations in the scientific community. While some are critical of its definition and scope, others embrace its power to act a silent political tool. This section helped establish the foundational theories surrounding virtual water and provided rationale for conducting the research. Definitions and ideas will be drawn from this section to better ground the results of the research.

2.4 *Water, Agriculture and the Environment under NAFTA*

2.4.1 Introduction

Perhaps the most scintillating and comprehensive debate in the environmental arena with respect to North American trade has been the issue about ‘bulk water export’ considerations under NAFTA. The NAFTA-water debate began when the Canadian public became concerned about proposals for huge artificial diversion of fresh water into the southern regions such as the United States and Mexico. In 1985, the Canadian Federal government released a report including nine water diversions from Canadian basins. Furthermore, the North American Water and Power Alliance (NAWPA) recognized huge diverted fresh water from the Canadian rivers to the Great lakes and Mississippi in the United States (Micklin, 1985; Sewell, 1985). These proposed huge artificial diversion proposals of water led the federal government to pursue the Canadian provinces to place a ban on fresh water exports in 1999 (Barlow, 2005). Although the supposition that water in its natural form falls under the NAFTA provisions is still highly debatable, one thing that is very evident and clear is that the U.S. has full and unconditional rights on Canada’s agricultural production. Since virtual water is water needed to produce an agricultural commodity, it falls under the category of a ‘good’ and escapes the contentious debate surrounding water and NAFTA. However, it is relevant to highlight the NAFTA-water debate since it will act as tool to assess the position of virtual water in NAFTA.

2.4.2 What is NAFTA?

On January 1, 1989, Canada entered into the first major bilateral free trade agreement with the United States in the Canada-U.S. Free Trade Agreement (CUSFTA). Five years later, the CUSFTA was expanded to include Mexico with the North American Free Trade Agreement (NAFTA). The NAFTA was the first major agreement that established a single trade zone between the “rich north” and the “poor south” (Curtis & Sydor, 2006). It created a free market in goods and helped in the liberalization of markets for services and capital in the three countries (Appleton, 1994). However, this liberalization has brought with it a lot of criticism and debate on a range of criteria from economic to political to social. Perhaps the greatest critique of agreement has been that it encourages bulk water export from Canada to the U.S. While some argue that water in its natural state (in lakes and rivers) is subject to NAFTA obligations, the governments of Canada, Mexico and United States explicitly oppose the argument (Johansen, 2003). What has not received attention in this debate is that water is also being exported in other forms, i.e., the virtual form, through the trade in agricultural products, especially livestock and livestock products. Under the Canada-U.S. FTA, both governments agreed to eliminate tariffs on agricultural trade within 10 years. This trade liberalization saw Canada's export of livestock and livestock products to the U.S. more than double within a very short span of time (Ash, 2005). Although trade statistics indicate a positive improvement in Canada's overall economic efficiency, there are hidden environmental implications of this free trade that has not been identified, especially on Canada's most pristine asset- its fresh water resources. This chapter provides a summary of the background of the NAFTA, a description of water and agriculture issues under the FTA, a review of government response to the issues, and a discussion on consequences of trade liberalization on Canada's water resources.

2.4.2.1 Background to the NAFTA

The North American Free Trade Agreement (NAFTA) is a regional agreement between the Government of Canada, the Government of the United Mexican States and the Government of the United States of America to implement a free trade area. It entered into force on January 1, 1994. NAFTA establishes a free trade area in accordance with Article XXIV of General Agreement on Tariffs and Trade (GATT) and specifies a gradual phase out all tariffs and quotas among the member countries by the end of 2008, the 15th year of the transition period. The objectives of the agreement, as elaborated more specifically through its principles and rules, including national treatment, most-favoured-nation treatment and transparency, and as stated in Article 102 (NAFTA Secretariat, 2004) are to:

a. eliminate barriers to trade in, and facilitate the cross-border movement of goods and services between the territories of the Parties;

b. promote conditions of fair competition in the free trade area;
c. increase substantially investment opportunities in the territories of the Parties;
d. provide adequate and effective protection and enforcement of intellectual property rights in each Party's territory;
e. create effective procedures for the implementation and application of this Agreement, for its joint administration and for the resolution of disputes; and
f. establish a framework for further trilateral, regional and multilateral cooperation to expand and enhance the benefits of this Agreement.

Apart from having its roots in the GATT, NAFTA is a product of two other U.S. bilateral trade agreements: the United States-Israel and the Canada-U.S FTAs. In fact, the CUSFTA provides and foundational framework of most of the 22 chapters of the agreement (Appleton, 1994). However, agriculture remains a sensitive area for all three countries and is the only area where NAFTA comprises three bilateral agreements. First, the CUSFTA agricultural provision has been included in NAFTA, while Mexico has negotiated two independent free trade agreements for agriculture, one with the United States and the other with Canada.

2.4.3 Water in NAFTA

2.4.3.1 Water as a "Good"

Whether the United States is entitled under the NAFTA to Canada's fresh water supply is a highly controversial issue that continues to be debated. Much of the controversy revolves around the question of whether water is a "good" under the NAFTA and whether or not this definition is limited in any manner, by the way in which the water is packaged. Article 201 (definitions of general application) of the NAFTA defines "goods of a Party" as follows:

> goods of a party means domestic products as these are understood in the *General Agreement on Tariffs and Trade* or such goods as the Parties may agree, and includes originating goods of that Party.

This means that any good covered by the GATT tariff heading is subject to all the provisions of the Agreement unless explicitly excluded from its text. A closer look into the GATT's Harmonized Commodity Description and Coding System (HCCS), which categorizes goods for custom tariff, reveals that the system contains a tariff item for water, which reads as follows:

> 22.01 waters, including natural or artificial waters and aerated waters, not containing added sugar or other sweetening matter nor flavouring; ice and snow.
>
> 22.01.10 Mineral water and aerated waters
>
> 10 Natural mineral water
>
> 90 Other
>
> 22.01.90 Other

An explanatory note states that the heading item covers "ordinary natural water of all kinds (other than sea water). Such water remains in this heading whether or not it is clarified or purified" (Appleton, 1994: 201).

There has never been any doubt that the NAFTA applies to water in containers such as bottles or water used in manufacturing beverages such as a soft drink, because in those cases the water has been transformed into a "good." However, since the GATT tariff heading includes all natural water, even ice and snow, then one can conclude that natural water, whether groundwater or surface, is a good too and falls under the provisions of NAFTA.

On the above basis, critics such as Wendy Holm (a resource economist and advisor on land and water use) argues that inclusion of 'all natural water other than sea water' under the NAFTA, gives "the United States (and possibly Mexico) unprecedented and irrevocable access rights to Canada's water resources in perpetuity" (Holm, 1993: 27). This view has also been supported by the Council of Canadians, a citizens' watchdog organization founded in 1985 that came to prominence in its fight against free trade.

The above position is, however, contrary to that taken by the federal government (Johansen, 2003) and a number of others. For example, Jon Johnson (1994), in one of his chapters in *The North American Free Trade Agreement: A Comprehensive Guide*, explains that unexploited resources such as oil or gas in the ground or water in lakes, rivers or aquifers are not “products” and therefore are not subject to these or any other NAFTA provisions. GATT does not define a “product”, which ordinarily means “something that is produced.” For a thing to be produced, it must go through certain processes such as extraction, collection, transportation, refinement, packaging etc. to be transformed into an article of commerce. Clearly natural water does not fall under the “produced” category.

Federal supporters of NAFTA have claimed that Canada’s legislation implementing NAFTA, the *North American Free Trade Agreement Implementation Act,* exclusively deals with protection against water and bulk water export. According to Section 7 of the Act:

> 7. (1) for greater certainty, nothing in this Act or the Agreement, except Article 302 (tariff elimination) of the Agreement, applies to water.
>
> (2) In this section, “water” means natural surface and ground water in liquid, gaseous or solid state, but does not include water packaged as a beverage or in tanks. (Johansen, 2001)

However, Wendy Holm and the Council of Canadians argue that section 7 of the implementing legislation “is insufficient protection without an amendment to the NAFTA itself and that only such an explicit exemption can protect Canada’s water resources from U.S. interests” (Johansen, 2001). It can be argued here that water which ends up “packaged as a beverage or in tanks” started out as “natural water”. There is no boundary to delineate between the exclusion and inclusion of water as a tradable good. This ambiguity in definitions and boundaries is the reason why there is so much debate surrounding NAFTA and water.

If virtual water is taken to be the amount of water required to produce an agricultural commodity, then the water has already been converted into a product and is subject to NAFTA (Article 201-definition of goods of a party) and GATT (HS Code 22.01.9 - all natural water other than sea water) provisions. Although virtual water does not fall under the contentious water-NAFTA debate, it is however important to highlight the criticisms by Holm, Barlow and others about how NAFTA is exploiting the water resources of Canada.

2.4.3.2 Chapter 11: National Treatment & Minimum treatment, Expropriation and Transfers

Two obligations under Chapter 11 of NAFTA that are relevant to the water debate are the national treatment provisions and paying compensation in cases of expropriation. The purpose of national treatment is to prevent a country from using internal measures, such as internal taxes and other internal charges, laws, regulations and requirements, in order to give protection to its nationals. Article 301 of the NAFTA adopts GATT's definition of National Treatment that requires that Parties provide national treatment for imported goods only:

> Each Party shall accord national treatment to the goods of another Party in accordance with Article III of the General Agreement on Tariffs and Trade (GATT).

The obligations under the provision mean that an American companies must be given rights and treatment equal to Canadian companies for access to goods and markets. Trading water cannot be limited to Canadian companies nor can there be limits on how it is traded, how much is traded or with whom it is traded (Johansen, 2001).

It has been suggested that the only way to 'turn off the tap' is for the federal and provincial governments to enact legislations that prohibit bulk water export. According to Holm (1993), the concern is further exacerbated by the extension of the principles of National Treatment to services and investment (Article 1102 and 1202). This ensures that neither construction of engineering works nor the flow of capital can be impeded. Hence, it will virtually impossible to stop large-scale diversion of water.

Chapter 11 also has a section (1110) for Minimum treatment, Expropriation and Transfers. The section states that:

> "No Party may directly or indirectly nationalize or expropriate an investment of an investor of another Party in its territory or take a measure tantamount to nationalization or expropriation of such an investment, unless"…. it meets certain criteria, including the payment of compensation.

A clear example of this was in 1996, when the province of British Columbia imposed a complete halt on water shiploads to California. Sun Belt Water Inc. of Santa Barbara, which used to have a permit to ship water in the mid-1990s to California, sought compensation of C$220 million from Canadian governments and filed a complaint under chapter 11 of the North American Free Trade Agreement (Barlow, 2005; Holm, 1993; Johansen, 2003). The claim was later withdrawn after a settlement agreement was reached between the parties, although the amount remains unknown (Hufbauer & Schott, 2005).

2.4.3.3 Government Responses to NAFTA- water dispute

In response to the general outcry and concern over the security of Canada's freshwater resources, the Canadian government developed a strategy to prohibit the bulk removal of water, including removal for export, from major Canadian water basins. The strategy comprised three key elements (for details see Dendauw, 2000; Johansen, 2003):

1. amendments to the *International Boundary Waters Treaty Act*:
   The principle strategy of the amendments were to prohibit transfers out of water basins between Canada and the U.S., especially the Great Lakes. The amending legislation was enacted into law and received Royal Assent on 18 December 2001; it came into force on 9 December 2002.

2. a joint Canada-United States reference to the International Joint Commission (IJC): to study the effects of water consumption, diversion and removal, including for export, from the Great Lakes. A report was submitted in March 2000, which contained key recommendations to protect the ecological integrity of the Great Lakes Basin.

3. a Canada-wide accord on bulk water removals: Under this accord, each jurisdiction would promise to adopt the federal government's strategy to prohibit bulk water removal. Although five provinces refused to sign the Accord, nine provinces do have specific bulk-water transfer policies in place (as of December 2006). Nunavut, the Northwest Territories, the Yukon, Ontario, New Brunswick, Nova Scotia, Prince Edward Island and

Newfoundland have all signed the Accord. Of these, New Brunswick is the only jurisdiction that does not have a specific policy in place to deal with bulk-water export. Nova Scotia enacted bulk-water legislation in 2000, PEI in 2002 and Newfoundland in 1999. Ontario adopted a regulation in 1999, but does not have specific legislation. Interestingly, all of the provinces that have not signed the Accord also have legislation in place restricting or prohibiting bulk-water export: BC and Alberta enacted legislation in the mid-1990s before the Accord existed, Saskatchewan in 2001, Manitoba in 2000 and Quebec in 2001 .

2.4.4 Agriculture and NAFTA

Of the 22 NAFTA chapters, only the Agriculture chapter does not contain a common text for all the three countries. The American-Canadian Agricultural Trade section of Chapter 7 incorporates a number of agricultural trade provisions from the CUSFTA. These provisions include: agricultural export subsides, quantitative restrictions on meat, rights of Parties under GATT among others.

The NAFTA definition of "agricultural good" in Article 708 covers the same products as those covered by the GATT Agricultural Agreement. HS Code 22.01 (all natural water other than seawater) therefore falls under not only in the agricultural good under Chapter 7 but also in the general provisions of NAFTA.

2.4.5 "Environment" in NAFTA

2.4.5.1 Why Environment was included

The NAFTA initiative in the 1990s provoked sharp reaction from the environmental and labour interests groups. They opposed the extension of U.S. trade relations, particularly for negotiations with Mexico (Hufbauer & Schott, 2005). The debate and the lobbying revealed a broad spectrum of views in the U.S. environmental community. There were three categories of environmental problems linked with NAFTA. First, environmentalists talked about cross-border pollution problems. The second category of concerns was that traded goods would not meet U.S. standards, either for the product itself or for the process by which it was being produced. The third category was concerns over the effects of NAFTA on both trade and investments. The unevenness in environmental standards between the developed North and Mexico would cause trade and investment distortions (Colyer, 2002; Hufbauer & Schott, 2005; Johnson & Beaulieu, 1996)

In response to this, the Bush administration had issued an action plan to make the NAFTA agreement more "green". However, this pact was greatly criticized in Clinton's presidential campaign (Johnson & Beaulieu, 1996). Post-election negotiations by the Clinton administration insisted on developing side agreements to address labour and environmental problems. These agreements, essentially, created tri-national commissions to handle the issues. For environmental issues, the North American Agreement on Environmental Cooperation (NAAEC) was negotiated and signed (Carpentier, 2006).

Thus, by incorporating environmental provisions in its text and the creation of the NAAEC, NAFTA was deemed to be the "world's greenest trade accord" (Hufbauer & Schott, 2005: 154).

2.4.5.2 What NAFTA has for the environment

The NAFTA itself does not contain any chapter on environmental measures. Instead, it contains provisions scattered throughout its 22 chapters that deal with the environment. In particular, the Agreement deals with the environment in six areas: 1) Preamble; 2) relationship with other agreements (chapter 1); 3) Sanitary and Phytosanitary measures sub-chapter (chapter 7B); 4) Technical barriers to trade chapter (chapter 9); 5) environmental measures in Investment chapter (chapter 11); and 6) dispute resolution provisions (chapter 20).

Preamble: NAFTA's Preamble has three items that relate to the environment. It states that the governments of Canada, Mexico and the United States will "undertake each of the proceedings in a manner consistent with environmental protection and conservation, "promote sustainable development" and "strengthen the development and enforcement of environmental laws and regulations" (NAFTA Secretariat, 2004).

Chapter 1: Article 103 and 104 of chapter 1 confirms NAFTA's precedence over other international agreements, except for trade provisions in five multilateral environmental agreements (MEAs).

Chapter 7B: on sanitary and phytosanitary (SPS) measures allows the signatories to take measures for the protection of human, animal and plant life or health. Article 712 requires that SPS measures (1) not arbitrarily discriminate among like goods; (2) be based on "*Scientific Principles*"; (3) be repealed or abandoned when no scientific basis exits for them; (4) be based on a risk assessment, where appropriate; (5) be applied only to the extent necessary to attain the desired level of production; and (6) not act as disguised restriction on trade (Hufbauer & Schott, 2005; NAFTA Secretariat, 2004).

Chapter 9: on technical barriers to trade encourages harmonization of standards between the parties. According to article 905 of this chapter, each party may "adopt, maintain or apply any standards-related measure, including any such measure relating to safety, the protection of human, animal or plant life or health, the environment or consumers…"(NAFTA Secretariat, 2004) provided they are non-discriminatory and do not create obstacles for trade.

Chapter 11: provision on environmental measures acknowledges that investment considerations can have a negative impact on environmental standards. The text in Article 1114 stipulates that parties adopt, maintain or enforce measures, consistent with the obligations of the Investment chapter, "to ensure that investment activity in its territory is undertaken in a manner sensitive to environmental concerns"(NAFTA Secretariat, 2004).

Chapter 20: provides the general procedures for environmental dispute settlement raised under the agreements (for details see Appleton, 1994; Chiu, 2003).

North American Agreement on Environmental Cooperation (NAAEC)

The NAAEC was signed by Canada, Mexico and the United States in August 1993 and came into effect in January 1, 1994. The NAAEC operates through the Commission for Environmental Cooperation (CEC), which is a three-member commission with a council of ministers, a Secretariat seated in Montreal, and a channel for NGO input, the Joint Public Advisory Committee (Hufbauer & Schott, 2005). It was developed to support the environmental provisions of the NAFTA by establishing a level playing field with a view to avoiding trade distortions and promoting environmental cooperation (Government of Canada, 2005).

The NAAEC contains three important principles: 1) improve environmental conditions in the three countries through cooperative initiative;s 2) establish proper implementation of environmental legislation; and 3) settle environmental disputes (Hufbauer & Schott, 2005). The primary gist of the agreement is that each country should enforce its own environmental laws, although the CEC has some enforcement powers. The CEC has the functions of overseeing the implementation of the agreement, providing a forum for discussing issues, cooperating in solving environmental problems, and adjudicating complaints about the failure of governments to enforce their environmental laws (Government of Canada, 2005; Secretariat of the Commission for Environmental Cooperation, 1993).

2.4.5.3 A critical review of NAFTA's environmental provisions

The NAFTA has been praised for being the first trade agreement to mention environmental provisions in its text. However, it is very important to examine the extent to which these provisions are effective in the free trade regime between the three countries.

For one, environment is not mentioned once in the agreement's objectives. This makes the three resolutions in the preamble vague and ineffective. According to Appleton (1994: 193), under the international rules of treaty interpretation, the "objectives" form the basis for the interpretation of the Agreement. While the Preamble can be looked at, it can only serve as a "secondary interpretive vehicle in cases where there is definitional ambiguity."

Although NAFTA addresses the environment in its Investment chapter, the provisions therein do not constitute a legally binding commitment on behalf of the signatories (Appleton, 1994; Johnson & Beaulieu, 1996). The provisions act as a diplomatic commitment by governments to acknowledge and maintain a certain level of environmental, health and safety standards, which they are free to adopt themselves. Johnson and Beaulieu (1996: 250) mention two scenarios where the provisions of NAFTA and NAAEC would fail: 1) If a party lowers its environmental standard (while still enforcing its domestic laws) to improve the competition between industries within its jurisdiction, then NAFTA or NAAEC rules do not apply. Hence, NAFTA would not be able to control the downward harmonization of the domestic standards in that region. 2) If a party lowers its environmental standards (while still enforcing its domestic laws) to attract investments, NAFTA provisions would discourage it, but do not provide any mechanism or binding commitments to avoid it.

The NAFTA provision also does not allow parties to adopt any policies that would affect trade: import restrictions, tariffs, bans on exports, ownership rules and penalties. This is a great obstacle in environmental protection. In case governments want to inhibit trade based on environmental concerns, they would have to prove through NAAEC's long and exacting processes that their actions are about environmental hazards and not excuses for avoid trading. According to Johnson and Beaulieu (1996: 253), trade sanctions in NAAEC's guidelines come at the end of the dispute settlement process. This is in complete contrast to GATT and CUSFTA procedures, which allow parties to exercise countervailing and antidumping measures at the beginning of the dispute.

Another critique to the NAFTA process is that it lacks openness and transparency with its trade rules and institutions for the public. Public participation is excluded in the main text of the agreement, but only included in the NAAEC provisions. However, as Johnson and Beaulieu (1996: 253) report, the NAAEC has failed "to extend new opportunities for public participation in NAFTA institutions and procedures".

Although one can point out the absence of many conceivable anti-environmental provisions from the NAFTA text, it does mean that it is a pro-environment document (Hufbauer & Schott, 2005; Johnson & Beaulieu, 1996). NAFTA does not benefit the environment directly. It only lessens the threat posed to domestic environmental laws and regulations by trade regulations and promotes economic growth that may result in additional resources being directed to the environment.

2.4.6 Conclusion

This section provided a discussion about NAFTA with a critical analysis of the NAFTA-water-environment debate. It can be concluded here that there are two lines of argument reinforcing the water trade discussion: First, under both GATT and NAFTA, barriers to trade of goods are prohibited (Article XI GATT and Article 309 NAFTA).

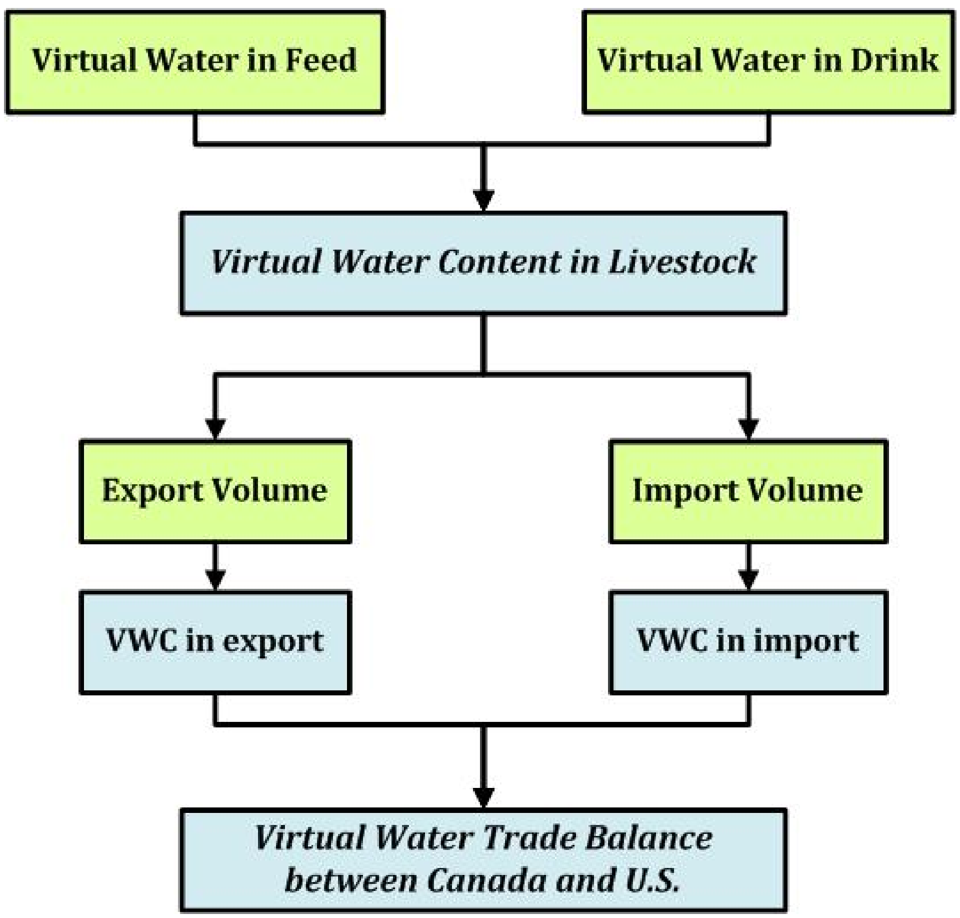
Secondly, with reference to discussion in section 2.4.3, it is unclear whether water in its natural states falls under NAFTA provisions. Since NAFTA Article 1102 requires foreign investors to be given the same treatment as national investors, it becomes virtually impossible to stop large-scale diversion of water. Moreover, it raises various doubts about NAFTA's already delicate environmental standpoint.

3 Methodology

3.1 Introduction

This chapter provides an outline of the methodology used in the calculation of the virtual water transfer in livestock and livestock products between Canada and the United States. The calculations will help establish the trend in virtual water flows between the two countries, before and after the signing of the NAFTA.

Figure 9: Methodological Framework of the Research



The general methodological framework of this research is shown in the schematic diagram provided in Figure 9. It provides a guide to the quantification of the virtual water content (VWC) and its flow between Canada and the U.S. for a particular type of livestock.

The virtual content in the animal feed and drink is first used to calculate the total amount of virtual water content in the animal category. The values are then multiplied by the export and import volumes to estimate the total virtual water in the trade flow between Canada and the U.S. The green boxes indicate secondary sources of data. These data are used to calculate the relevant information needed for this research, indicated by the blue boxes.

3.2 Virtual Water Calculation

The virtual water flow (VWF) through the trade in livestock and livestock products is calculated based on a method developed by Chapagain and Hoekstra (2003). They calculated the VWF by multiplying trade volumes (measured in tonnes per year) with the virtual water content (VWC) (in cubic metres per ton) in the traded products. The key assumption when calculating the VWC of a livestock or its products is that the product "is fully produced within the country, with the animal feeding, drinking and living on domestic resources" (Chapagain & Hoekstra, 2003: 11).

The equation to calculate virtual water flow is:

$$VWF[n_e, n_i, c] = T[n_e, n_i, c] \times VWC[n_e, c] \quad \text{............... Equation 1}$$

Source: Hoekstra & Chapagain, 2007

in which, VWF denotes the virtual water flow (m^3/year) from exporting country n_e to importing country n_i as a result of trade in a commodity c; T the commodity trade (ton/year) from the exporting to the importing country; and VWC the total virtual water content (m^3/ton) of the commodity in the exporting country.

3.2.1 Equations for calculation of virtual water

The VWC of a live animal has been defined as the "total volume of water that was used to grow and process its feed, to provide its drinking water, and to clean its housing and the like" (Chapagain & Hoekstra, 2003: 11) from birth to the end of its lifespan. These three distinct components in the VW calculation fall under two categories. The VWC in feed and drink is the "product water" since this water is used to support the animal in its growth and maintenance of bodily functions and is hence embedded in the body of the animal. The third component of the VWC calculation falls under "service water".

Drawing from Allan's definition of virtual water as being the water used to produce agricultural commodities and improvising on Chapagain & Hoekstra's (2003) definition, this research will calculate virtual water of animal and its primary products based on the product water alone. The service water aspect of livestock production has not been calculated since it has been assumed that water for servicing returns to the environment (in quantity if not quality) and is not directly consumed by the animal. Service water is not necessarily embedded in the body of the livestock. When considering virtual water trade in terms of water lost from the local ecosystem, it is more meaningful to use a *restrictive* (estimating only water embedded in the commodity) definition of virtual water than the expansive definition set by Allan and the Chapagain team.

Furthermore, unlike the UNESCO-IHE report (Chapagain & Hoekstra, 2003), which calculated the total water used by an animal category over its entire lifetime, this research will adjust the total water used by the animal to indicate the average amount of water that is embedded in it and its product. Thus, the equation for the calculation of the virtual water content is:

$$VWC_a[e,a] = VWC_{drink}[e,a] + VWC_{feed}[e,a] \text{...............} \quad \textbf{Equation 2}$$

Source: adapted from Chapagain & Hoekstra, 2003

where, $VWC_a[e,a]$ is the virtual water content of animal a in exporting country e, in this case, Canada and the United States. $VWC_{drink}[e,a]$ and $VWC_{feed}[e,a]$ are the virtual water contents from feeding and drinking.

VWC $_{drink}$: The VWC from drinking water is defined as the total volume of water consumed over the total lifespan of the live animal. For the purpose of this research, an average daily amount of drinking water was first calculated using infant and adult water requirements and then multiplied by the total age of the animal to determine the VWC $_{drink}$. An average value for daily water requirement accounts for the differences in water intake during the various stages of growth of the animal. It is assumed that a linear relationship exists between water intake and age until adulthood. The equation is as follows:

$$VWC_{drink}[e,a] = avg.q_d[e,a] \times Age[e,a] \text{............. } \textbf{Equation 3}$$

Source: adapted from Chapagain & Hoekstra, 2003

Where,

avg. q_d [e,a] = the average daily drinking water requirement of animal ‘a’ in exporting country ‘e’, expressed in m^3/day

Age [e,a] = Total age of the animal ‘a’ in exporting country ‘e’, in days

VWC $_{feed}$: The VWC of the feed consumed by a live animal over its lifetime is defined as the total VWC in the various feed ingredients and the water required to prepare the feed mix. The VWC of the feed ingredients is calculated by multiplying the specific water demand of feed crops with the average quantity of feed consumed by the animal. Similar to the proposition in the calculation of the VWC $_{drink}$, an average value is taken to account for the differences in feed requirements during the various stages of growth of the animal and assuming there is linearity between feed volume and age until adulthood. The equation to calculate VWC $_{feed}$ is:

$$VWC_{feed}[e,a] = \sum_{c=1}^{n_c} SWD[e,c] \times avg.C[e,a,c] \text{............. } \textbf{Equation 4}$$

Source: adapted from Chapagain & Hoekstra, 2003

Where,

SWD [e,c] = specific water demand of crop ‘c’ in exporting country ‘e’, expressed in m^3 / ton. It is calculated by dividing the crop water requirement by the crop yield of the exporting country.

avg. C [e,a,c] = the average quantity of feed crop ‘c’ consumed by animal ‘a’ in exporting country ‘e’(calculated using infant and adult values), expressed in tons/day

The water required to prepare the feed mix is taken to be 50% of the volume of total roughages fed to the animal per year.

3.2.2 Defining the variables

3.2.2.1 Drinking Water Requirement [q_d]

Fifty to 80 percent of an animal's live weight is essentially water (Agriculture and Agri-food Canada, 2001; Ministry of Agriculture and Lands B.C., 2006). Livestock acquire water either through their feed or from natural sources. According to Ministry of Agriculture and Lands B.C. (2006), the drinking water requirements depend on variables such as:

1. Kind and size of animal
2. Physiological state of animal
    - lactating cows require an extra 0.86 kg (litre) water per kg of milk
    - pregnant cows and growing animals 30 to 50% increased consumption
3. Level of animal activity
4. Type of diet and dry matter intake
5. Water quality
    - palatability & salt content affects water consumption
6. Water temperature
    - 10 degrees Celsius desirable; from 4 to 18 degrees acceptable
7. Water trough space
    - crowding at a trough may limit water to some livestock
8. Air temperature (usually the most important, especially for outdoor livestock)

    A general ‘rule of thumb’ when calculating the drinking water requirements of livestock based on weather conditions is:

    - cool weather (below 15 ºC): 4 L per 45 kg animal weight (1 US gal/100 lbs)
    - hot weather (above 25ºC): 8 L per 45 kg animal weight (2 US gal/100 lbs)

For the purpose of this study, average values as indicated in Table 6 are used in VWC calculation and it is assumed that demand for water is constant regardless of changes in ambient temperature and/or other stress-related conditions.

Table 6: Average daily water consumption for each category of livestock (US gallons/day)

TYPE OF ANIMAL	DESCRIPTION	US GPD	TYPE OF ANIMAL	DESCRIPTION	US GPD
BEEF			SWINE (with wash water)		
cow with calf *	1,300 lb	12	farrow - finish	--	24 / sow
dry cow/mature cow *	1,300 lb	10	farrow - late wean	50 lb	8 / sow
calf *	250 lb	3	farrow - early wean	15 lb	6.5 / sow
feeder – growing **	400-800 lb	6 - 9	feeder	50 - 250 lb	2 / pig
feeder – finishing **	600-1,200 lb	9 - 12	weaner	15 - 50 lb	0.6 / pig
bull	--	12	POULTRY		
DAIRY			broiler	per 100	4.2
milking * (with wash water)	holstein	36	roaster/pullet	per 100	4.8
dry cow/replacement	holstein	12	layer	per 100	6.5
calf	to 550 lb	3.5	breeder	per 100	8.5
SHEEP AND GOATS			turkey - grower	per 100	15.5
ewe/doe	--	2.5	turkey - heavy	per 100	19
milking ewe/doe	--	3.5	OSTRICH	--	1.2
feeder lamb/kid	--	2	DEER, LLAMA, ALPACA	--	2.5
BISON, HORSE, MULE	--	12	ELK, DONKEY	--	6

* For peak water use on days above 25^0 C multiply gpd by 1.5

** For peak water use on days above 25^0 C multiply gpd by 2

Source: Ministry of Agriculture and Lands B.C., 2006

3.2.2.2 Average Weight [W_a] and Age [Age_{adult} and Age_{infant}]:

The average weight and age of different breeds of livestock are available in various literature sources. Weight of an animal is dependant on environmental variables such as temperature and feed. The data used for this research were derived from sources that were more reflective of the Canadian environment and standard. For detailed descriptions of different animal categories, refer to Appendix 1.

Table 7: Livestock production parameters

Animal	Avg. Weight (lb.)	Conversion (ton)	Avg. Age (months)	Other parameters
Beef Cattle				
cow with calf	1,300	0.59	-	Live Weight at slaughter: 590-630 kg
dry cow/mature cow	1,300	0.59	36	
calf	250	0.11	5	
feeder-growing	400-800	0.18-0.36	-	
feeder-finishing	600-1200	0.27-0.54	-	
bulls	1,300	0.59	-	
Dairy Cattle				
Calves	550	0.25	0-12	
Heifers/ Dry Cows	1000	0.45	12-36	Live Weight at slaughter: 270-450 kg
Milking Cows	1000	0.45	36-120	Milk Prod. during Lactation: 7400 (kg/yr) No. of Lactations: 7
Swine				
farrow-finish	-	-	12	Live Weight at slaughter: 90 kg
farrow - late wean	50	0.02	-	
farrow - early wean	15	0.01	-	
feeder	50-260	0.02-0.12	-	
weaner	15-50	0.007-0.02	0.5	
Sheep & Goats	100	0.05	18-24	

Source: adapted from Chapagain & Hoekstra, 2003; Ministry of Agriculture and Lands B.C., 2006

3.2.2.3 Feed crop [C]

In Canada, feed crops fall under two distinct categories: grain based rations and roughages. Box 1 highlights Statistics Canada (2003) definitions of the feed crops. For estimating the VWC in feed, the '*average feed crop*' data for the various categories of livestock have been taken from the web publication of the Statistics Canada (2003) report, entitled 'Livestock Feed Requirements Study' (Refer to Table 8).

The daily feed requirement of an animal depends upon a number of variables, such as breed, weight, farming system, ambient temperature, etc (Chapagain & Hoekstra, 2003). It is not within the scope of this study to consider each variable and hence the standard set by Statistics Canada (2003) is the basis for all calculation. The typical feeding procedures and requirements in Canada for the main categories of livestock are as follows:

Cattle and Sheep: These livestock are fed outdoors or indoors. Common methods of outdoor feeding include pasture and rangeland grazing in open fields; seasonal feeding on the ground or in portable or fixed feeders; and feeding in feed bunks or mangers. Indoor feeding is usually in feed bunks or mangers. Several different types of feed are fed to livestock including hay, silage, grain and prepared rations.

Swine/Pigs: Typical swine and pig feed includes barley, wheat, soybean meal, canola meal, field peas or manufactured feeds. They are fed indoors once or twice each day.

Poultry: Poultry birds, including layers, broiler breeders, turkeys and broiler chickens, are kept inside a barn and are typically fed several times a day. Grain and other feedstuffs form part of the poultry feeds.

Box 1: Definition of various types of feed crop

<u>Grain based feed definitions</u>

- ***Complete Grain Based Ration*** - includes the total quantity of all grains, supplements, minerals, fats, sweeteners, animal by-products, etc., included in a grain based ration whether mill feeds or mixed on farm.
- ***Total Grain*** - is the sum of wheat, oats, barley, other small grains, grain corn, dry peas, soybeans, and canola meal and mill screenings.
- ***Non-grain Portion*** - is the quantity of all the non-grain components of the complete grain based rations including supplements, minerals, fats, sweeteners and animal by-products.

<u>Roughage Definitions</u>

- ***Pasture*** - includes unharvested forages consumed by animals while on pasture converted to 100% dry matter.
- ***Dry hay*** - includes all harvested grass forages harvested as dry hay converted to 100% dry matter.
- ***Silage*** - includes all grass forages, green chop and forage corn harvested as silage converted to 100% dry matter.
- ***Other Roughages*** - includes all other roughage including straw, by-products, beet pulp, vegetable waste, etc. converted to 100% dry matter.
- ***Total Roughages*** - is the sum of pasture, dry hay, silage and other roughages.

Source: Statistics Canada, 2003

Table 8: Average feed composition for different animals in Canada (in ton/year)

Feed crop	Beef cattle	Beef rep heifer < 1 yr	Dairy Calves < 1 yrs	Dairy Heifers	Dairy Cow	Weaner	Pigs	Sheep
Wheat	0.006	0.004	0.023	0.008	0.091	0.001	0.028	0.001
Oats	0.041	0.089	0.064	0.011	0.02	0	0	0.006
Barley	0.09	0.042	0.157	0.111	0.748	0.003	0.063	0.026
Other small grain	0.002	0.003	0.027	0.018	0.052	0	0	0.001
Grain corn	0.002	0.014	0.263	0.186	1.443	0.013	0.12	0.005
Dry peas	0.002	0.004	0	0	0.003	0.001	0.007	0.001
Soybean meal	0.002	0.002	0.077	0.043	0.266	0.005	0.032	0.002
Canola meal	0.006	0.008	0.021	0.005	0.095	0	0.012	0.001
Mill screen	0.014	0.011	0.035	0.006	0.218	0	0.003	0.001
Total grain	0.165	0.177	0.666	0.387	2.938	0.023	0.266	0.043
Non grain portion	0.003	0.003	0.025	0.011	0.162	0.004	0.011	0.001
Pasture	2.043	0.524	0.059	0.542	0.326	-	-	0.171
Dry Hay	1.523	0.528	1.063	1.459	1.027	-	-	0.205
Silage	0.47	0.129	0.425	1.335	2.976	-	-	0.034
Other roughages	0.479	0.1	0.054	0.029	0	-	-	0.003

Source: Statistics Canada, 2003

3.2.2.4 Specific water demand [SWD]

The specific water demand (SWD) of a crop is the volume of water required to produce a certain quantity of the crop and is expressed in m^3/ton (Chapagain & Hoekstra, 2003: 12). The calculation of the SWD of a crop would require complicated modeling and data collection mechanism, which is beyond the scope of this research. For calculating the VWC feed, the SWD for Canada have been taken from Chapagain and Hoekstra (2003).

Table 9: Canada's specific water demand of feed crops (m^3/ton)

Feed crop	SWD (m^3/ton)
Wheat	1441
Oats	2328
Barley	1098
Other small grain	897
Grain corn	381
Dry peas	1377
Soybean meal	1227
Canola meal	1098
Mill screen	1441
Non grain portion	381
Pasture	445
Dry Hay	494
Silage	494
Other Roughages	445

Source: Chapagain & Hoekstra, 2003

3.2.3 Calculation of VWC of livestock and its product

Equation 2 (pg. 51) is the basis for the calculation of the total VWC of a livestock category. However, it is reasonable to assume that not all water consumed by the animal remains in its body throughout its lifetime. While some percentage of the water is excreted, the remaining portion is used to maintain bodily functions: regulation of body temperature, digestion, waste removal, and the absorption of nutrients. The water content in the body of an animal depends on its class and breed. Lactating animals generally require more water than others. For the purpose of this research, the WC has been taken to be constant regardless of class, breed and physiology of the animal. Table 10 below outlines the water content (WC) of empty body weight of the various animal categories:

Table 10: Water Content of different animal category

Animal category	Water Content (%)	Source
Beef Cattle	54.9 - 57.8	Gad & Preston, 1990
Dairy Cow	62.4 – 69.0	Board of Agriculture and Natural Resources, 2001
Swine	51.0 – 82.0	Kraybill, Goode, Robertson, & Sloane, 1953
Sheep and Lamb	43.2 - 48.6	Hix, Evans, & Underbjerg, 1953
Broiler Chicken	64.0	Latshaw & Bishop, 2001

It is assumed here that the value for the WC is the percentage of water used throughout the lifetime of the animal to maintain its vital bodily functions. The total water used in feed and drink throughout the animal's lifetime is multiplied by the WC, in order to estimate the actual amount of water that is embedded in the animal. The value obtained from the summation of VWC $_{feed}$ and VWC $_{drink}$, i.e. the total VWC, is multiplied by the WC to give the following equation:

$$Actual\ VWC_a[e,a] = \left(\sum VWC_{feed}[e,a] + VWC_{drink}[e,a]\right) \times WC_a$$ **……….. Equation 5**

Where,

WC_a= the water content of empty body weight of animal, expressed as a percentage

3.2.3.1 VWC in primary products

The primary products of an animal are the products derived directly from the animal, while secondary products are products derived from primary products. For the purpose of this investigation, only the primary products for each animal category have been considered. The primary products for animal categories are: beef/veal for beef cattle, milk for dairy cow, pork for swine and mutton for sheep and lamb.

Similar to the VWC calculation, "service water" for processing the primary products has not been accounted in the total VWC calculation. Since the meat of the animal is the primary product for each category (except for dairy), the hot carcass weight (HCW) of each animal is the true indicator of the amount of water embedded in the animal's primary product. HCW is the remaining weight of the animal after eliminating the hide, head, feet, tail, entrails and gut fill at the point of slaughter (OMAFRA, 2005). This value is usually expressed as a percentage of the total body weight.

Hence, % carcass weight ≈ amount of VWC_a carried over to its primary product.
Table 11 below shows the percentage of body weight used as carcass meat.

Table 11: Total carcass weight of animal category

Primary Product	Carcass Weight (%)	Source
Beef/ Veal	44 – 55	Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2005
Pork	45.81	Gnaedinger, Hix, Reineke, & Pearson, 1963
Mutton	43.2 – 48.6	estimated from Silva et al., 2006; Silva et al., 2007
Broiler Chicken	72.7	Chapagain & Hoekstra, 2003
Milk	87.6*	Board of Agriculture and Natural Resources, 2001

* percentage composition of water in milk

The total VWC in the primary product of an animal ($VWC_{primary}$) is thus calculated by multiplying the percent of HCW with its 'product function'. The product function can be defined as the amount of VWC per ton of animal. The equation for calculation of the primary product is:

$$VWC_{primary}[e,a] = \frac{TotalVWC_a[e,a] \times HCW_a}{W_a[e,a]}$$ **................ Equation 6**

Where,

$VWC_{primary}$ [e,a] = the VWC of the primary product of animal ‘a’ in exporting country ‘e’, expressed in m^3/ton

HCW_a= Hot Carcass Weight of animal ‘a’ in ‘percentage of body weight’

W_a [e,a] = average live weight of animal ‘a’ in exporting country ‘e’ at the end of its life span, expressed in tons

In the case of milk, the VWC has been estimated by multiplying production volumes with the percent of water in milk (87.6%).

3.3 Calculation of VWF in trade

Equation 1 (pg. 51) is the basis for the calculation of the virtual water flow between Canada and the U.S. As a final step in the VW estimation, trade volumes of a commodity are multiplied by its VWC to calculate the VWF (in m^3/year). The VWF in exports from Canada is subtracted from the VWF in imports from the U.S. to estimate the difference in trade in VWF between the two countries.

3.4 Provincial details

In order to study localized impacts of trade on water resources of Canada, two provinces, Alberta and Ontario have been selected as case study areas. The hydrological make-up of the areas vary considerably. Alberta is a dry and arid region and relies heavily on irrigated water, while Ontario is water-rich and agriculture is primarily rain-fed. The areas were chosen due to their expansion and specialization in the livestock sector and growing cross-border trade with the U.S. since the initiation of the NAFTA. Evaluating the VWF for the two areas will provide a comparative analysis of the extent of the impacts on water resources, under different conditions of supply and use, due to the trade of livestock and livestock commodities from the area.

3.4.1 Case Study Area 1: Alberta

Agriculture is one of Alberta's largest economic producers. About 30% of Alberta's total land area is used for crop and livestock production (AMEC Earth & Environmental, 2007; Coote & Gregorich, 2000).

Water Sources:

In 2005, about 46 million acres of land were irrigated in Alberta (AMEC Earth & Environmental, 2007). More than three-quarters of this area is located in the 13 irrigation districts in southern Alberta in the Saskatchewan River Basin and Milk River Basin, where private irrigation projects are also concentrated. The Oldman and Bow river systems, whose flows come mainly from snowmelt in the Rocky Mountains, are the water source for all the irrigation districts. To capture and store spring runoff for irrigation use later in the summer, 48 reservoirs with a combined usable storage of 2826 thousand cubic metres have been constructed on these river systems (Coote & Gregorich, 2000). These reservoirs also supply water for municipal and industrial use, livestock watering, on-farm domestic use, and recreation.

Water Utilization:

According to the Alberta environment report (AMEC Earth & Environmental, 2007), the total volume of water allocated to livestock watering was 158 Mm^3 in 2005; with 3.9 Bm^3 being allocated for irrigation. Out of this allocation, 65% of the water allocated for livestock was actually consumed, while crop watering used 54% of its allocation.

The breakdown of crops grown in Alberta in 1997 was 40% cereals, 40% forages, 9% oilseeds, 11% specialty crops, and 0.5% other crops (Coote & Gregorich, 2000) — crops needed for the growth and production of livestock.

Trends in the livestock sector and trade with U.S.:

The cattle herd in Alberta has been expanding at a terrific pace in the past several years. From January 1991 to 2006, the Alberta cattle inventory increased 33 percent to 6.3 million head (see Appendix 3). Alberta's beef industry has expanded for several reasons. *Alberta Environment* (AMEC Earth & Environmental, 2007) reports that Alberta is one of the lowest-cost producers of fed cattle in North America. Large local supplies of barley have been the key to increased cattle feeding in Alberta. Low feeding costs have increased local fed cattle supplies. This has resulted in expanded cattle exports to the United States. In 2006, U.S. beef cattle imports from Alberta totalled approximately 690,000 head worth 7 million Canadian dollars (refer to Table 02 in Appendix 6).

Concerns

The amount of water used in the livestock/agriculture sector is high considering that Alberta only has an annual flow volume of 56.1 Bm^3. In addition, intensive livestock operations are on the rise in Alberta. ILOs are extremely water intensive operations and puts significant demands on water resources. According to a water use forecasting assessment (highlighted in AMEC Earth & Environmental, 2007), livestock populations and water demand will increase annually at rates of between 0.5 percent and 2.2 percent per year. In 2025, livestock water use is projected to increase by 46 percent from 2005. This projected increase may surpass the capacity of the province to supply water to the agricultural sector. Unless, water management strategies are employed, this region will soon face increasing conflicts among its water users and growing threat to the integrity of its aquatic ecosystems.

3.4.2 Case Study Area 2: Ontario

Agriculture is the second largest economic sector and the third largest consumer of water, accounting for 20% of total consumption in Ontario, compared to 38% for municipal water supply and 28% for manufacturing (de Loë et al., 2001). Most of the agricultural activities are concentrated in the south-western parts of Ontario, which is facing rapid urban growth and increased competition among other water-intensive industries.

Water Sources:

In Ontario, water for agriculture is derived from a combination of surface sources, such as, streams, rivers, lakes, ponds and groundwater sources, such as, shallow sand and gravel aquifers, deep bedrock aquifers). The major surface water sources for agriculture are Lake Huron and tributaries of Lake St. Clair River and Lake Erie (Vandierendonck, 1996).

Water Utilization:

Crop production in Ontario is generally sustained by rain-fed irrigation. Agricultural water use is primarily concentrated during the months of June, July and August when approximately 54% (de Loë et al., 2001) of water withdrawn is used for irrigational purposes. However, some year-round activities, such as livestock production and greenhouse crops, also consume a substantial amount of water. Total water use as estimated by de Loë et al. (2001), was 173.76 million m^3/year in 2001, of which livestock sector used 30%.

Trends in the livestock sector and trade with U.S.:

Ontario specializes in the dairy cattle and swine sector. However, as reported by Ontario Ministry of Agriculture, Food and Rural Affairs (2006), there has been a steady decline in the number of farms in Ontario since the 1980s due to rapid urbanization and increased competitiveness from the west.

The U.S. has been a net importer of Ontario slaughter hogs. In 2006, approximately 1.3 million swine head were traded across the border, an increase by a factor of 8 compared to that of 1993 (see Table 02 of Appendix 7).

Concerns

Ontario has approximately 18% of the total Canadian freshwater area and may seem to have abundant water wealth. However, a closer look reveals that there is enormous variability across the province in terms of quantity, quality and reliability of water. Ontario's rapid urban growth has not only increased the competition between agriculture and other sectors, but has also increased the demand for water within agriculture for certain crops, e.g., sod and nursery stock (de Loë & Moraru, 2004). Localized droughts have been reported almost every year somewhere in the province from 1960-1989 and this has caused serious problems for farmers in some regions who are reliant on large quantities of water (de Loë et al., 2001). Runoff and other sources of contamination from agricultural operations often degrade surface and groundwater quality. In a survey done in 1992 on ground water quality, 34% of all wells had high coliform bacteria count and 7% contained nitrates and bacteria exceeding the maximum pollution standards (Coote & Gregorich, 2000; de Loë & Moraru, 2004).

3.4.3 Calculation of VW for Alberta & Ontario

Due to the unavailability of quantitative data on livestock numbers for the two provinces, monetary values for export and import quantities were compared. Prices (in hundredweight) were then collected for non-purebred cattle, swine and sheep from various Statistics Canada publications and used to approximate the number of animals being traded. The approximate "number of head" calculated was then multiplied with the VWC (m^3/animal) of the commodity to calculate the VWF in m^3/year. The following conversion formula was applied:

For cwt to tons:

$$No.of\ heads = \left[\frac{Total\ export\ (or,\ import)}{conversion\ factor \times weight\ of\ animal \times price\ per\ cwt} \right] \text{...... Equation 7}$$

Where,

Conversion factor = is the conversion number needed to convert metric tons to cwt, [1 metric tons = 20 cwt (hundredweight)]
Weight of animal = is the weight of the animal, in metric tons
Total export (import) = is the total value of export or import in Canadian dollar C$
Price = per 100 weight (cwt) C$

3.5 Summary of data sources

The table below summarizes the databases used to extract trade values for each of the animal category and its products:

Table 12: Data Source for Export and Import volumes by category

TYPE OF DATA	DATABASE
Export and Import Quantities of Cattle: Dairy and Beef (1993-2006)	1. Agriculture and Agri-food Canada: Red Meat Market Information URL: http://www.agr.gc.ca/redmeat/almrcalendar.htm 2. Statistics Canada, Catalogue no. 23-012-XIE (2006 vol.5 no.2) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 3. Alberta Agriculture and Food: Alberta Trade in Beef and Live Cattle: A Five-Year Perspective (2003; 2005; 2007a) URL: http://www1.agric.gov.ab.ca/

TYPE OF DATA	DATABASE
Export and Import Quantities of Beef/ Veal (1989-2006)	1. Agriculture and Agri-food Canada: Red Meat Market Information URL: http://www.agr.gc.ca/redmeat/almrcalendar.htm 2. Alberta Agriculture and Food: A Five-Year Perspective (2003; 2005; 2007a) URL: http://www1.agric.gov.ab.ca/ 3. U.S. Trade Internet System, United States Department of Agriculture Foreign Agricultural Service URL: http://www.fas.usda.gov/ustrade
Export and Import Quantities of Milk (1989-2006)	1. U.S. Trade Internet System, United States Department of Agriculture Foreign Agricultural Service URL: http://www.fas.usda.gov/ustrade
Export and Import Quantities of Swine (1989-2006)	1. Statistics Canada, Catalogue no. 23-010-XIE (2007d) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 2. Alberta Agriculture and Food: Alberta Trade in Pork and Live Hogs - A Five-Year Perspective (2004; 2007b) URL: http://www1.agric.gov.ab.ca/
Export and Import Quantities of pork (1990-2005)	1. Agriculture and Agri-food Canada: Red Meat Market Information URL: http://www.agr.gc.ca/redmeat/almrcalendar.htm 2. U.S. Trade Internet System, United States Department of Agriculture Foreign Agricultural Service URL: http://www.fas.usda.gov/ustrade
Export and Import Quantities of Sheep & Lamb (1989-2006)	1. Statistics Canada, Catalogue no. 23-011-XIE URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 2. Statistics Canada, Catalogue no. 23-603-XIE; 2002-2006 URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 3. Agriculture and Agri-food Canada: Red Meat Market Information URL: http://www.agr.gc.ca/redmeat/almrcalendar.htm 4. U.S. Trade Internet System, United States Department of Agriculture Foreign Agricultural Service URL: http://www.fas.usda.gov/ustrade
Export and Import Quantities of Mutton (1989-2006)	Same as above (sheep and lamb)

TYPE OF DATA	DATABASE
Export and Import Quantities of Broiler Chicken (1990-2006) & Chicken meat (1996-2006)	1. U.S. Trade Internet System, United States Department of Agriculture Foreign Agricultural Service URL: http://www.fas.usda.gov/ustrade
Alberta Statistics	1. Trade Data Online, Industry Canada URL: http://strategis.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php#tag 2. Statistics Canada, Catalogue no. 23-012-XIE (2006 vol.5 no.2) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 3. Statistics Canada, Catalogue no. 23-010-XIE (2007d) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 4. Alberta Agriculture and Food: Agriculture Statistics Yearbook 2006 (2007) URL: http://www1.agric.gov.ab.ca/
Ontario Statistics	1. Trade Data Online, Industry Canada URL: http://strategis.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php#tag 2. Statistics Canada, Catalogue no. 23-012-XIE (2006 vol.5 no.2) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 3. Statistics Canada, Catalogue no. 23-010-XIE (2007d) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html 4. Statistics Canada, Catalogue no. 23-011-XIE (2006) URL: http://dsp-psd.tpsgc.gc.ca/Collection/Statcan/index-e.html

3.6 Conclusion

This chapter provided the equations needed for the VWC and VWF calculations. The limitations and assumptions used in the calculation process are clearly laid out to avoid confusion and ambiguity. Variables were defined and data sources were highlighted. The chapter also gave a brief summary of the two case study areas of the research. The methodology indicated in this chapter will help establish the trend in VWF between the two countries, before and after signing of the NAFTA.

4 Research Findings

4.1 Introduction:

This chapter summarizes the research findings. The study was conducted in three parts. First, the background literature on NAFTA was studied and trade data were collected to understand the NAFTA regime and study the impacts on Canadian exports of meat and meat products from the 1990s. The trade data were collected from provincial agricultural ministries and Statistics Canada. Secondly, datasheets were created to calculate the VWC in the various categories of animals and ultimately to estimate VWF between the two countries. Finally, two provinces, namely Alberta and Ontario, were chosen as case study areas to investigate localized impacts on water resources due to trade under NAFTA.

The list below summarizes the major assumptions used in the methodology of this research:

1. Beef/dairy cattle, swine sheep and chickens are the major categories of livestock exported to the U.S. The research limits its investigation to only these groups and their associated primary products, namely beef, milk, pork, mutton and chicken meat.
2. The livestock and its products are produced fully within the exporting country. ‘Produced’ means that the animal feeds drinks and lives off domestic resources.
3. Environmental conditions and meat production capacities are identical in Canada and the U.S.
4. ‘Service water’ used in the cleaning and watering purposes for livestocks returns to the environment and is not embedded in the body of an animal.
5. All livestock are reared in ideal conditions and do not suffer any stress related conditions at any part of their lifecycle.
6. There is a linear relationship between food/water intake and the age of the animal.
7. The percentage of water content of an animal is the true indicator of the amount of water needed by an animal throughout its lifetime to survive in ideal conditions.
8. The percentage of hot carcass weight (HCW) is the amount of water in the primary product of animal.

9. The values for VWC of an animal are overestimates and serve as an approximation for the actual water used by an animal category.
10. The VWC of an animal category is constant across different breeds.

4.2 VWC calculation results

The full calculation of the VWC of a live animal and its primary products for Canada are depicted in Appendix 4. Table 13 shows the results of the VWC for the different animal categories:

Table 13: VWC in different animal category and related primary products

Animal Category	Primary Product	Unit	VWC
Beef Cattle		m^3/ animal	2746.4
	Beef	m^3/ ton	2251.15
Dairy Cattle		m^3/ animal	17,599.34
	Milk	m^3/ litre	87.6% of milk vol.
Swine		m^3/ animal	92.67
	Pork	m^3/ ton	355.22
Sheep		m^3/ animal	151.41
	Mutton	m^3/ ton	1392.93
Broiler Chicken		m^3/ animal	3.74
	Chicken meat	m^3/ ton	1241.03

It can be observed from the figures above that the VWC of most of the meat products is higher that the VWC of the animal itself. This is due the fact that the primary products are measured in m^3/ton. For smaller animals such as chickens, it takes a great many animals to yield a ton of meat. For beef cattle, the number is much closer.

Comparing the VWC in m^3/animal, the value for dairy cow is very high compared to any of the live animal categories, followed by beef cattle. In the primary products, the VWC per ton of beef cattle tops the chart by being almost twice that of poultry (broiler chicken), implying that the production of red meat requires more water per ton than white meat. This has implications when considering the dietary trends of red and white meat in North

America. Swine is the most water efficient in terms of water use during lifetime and usage per ton (approximately one sixth of that used by beef cattle).

It should be noted that the assumptions 4 to 10 listed in section 4.1 above holds true for all the VWC calculations, except for the calculation of milk, where the water content in milk is taken to be the indicator of the amount of water embedded in it.

4.3 VWF calculation results

4.3.1 Trends in livestock trade

4.3.1.1 Cattle

According to the trade data in Appendix 5, Canada exports to the U.S. significantly more cattle than it imports. The major trading partner is the United States, which holds almost 99% of all Canada's cattle export share. Since the onset of the NAFTA in 1994, the exports of beef and dairy cattle to the United States have fluctuated from year to year; but on average have generally increased. Excluding the four years (2003-2006) when trade was stifled by the BSE restrictions, the average growth in beef cattle exports has been 63% and 270% for dairy cattle (comparing 1994 and 2002 export values). Significant increases in import quantities from the U.S. occurred after 1998 due to changes in Canada's policies and market re-structuring (see 2.2.4).

If we compare the VWF between the two nations from 1994 until 2006, it can be seen that Canada exports 17 times more VW in beef cattle and 26 times more VW in dairy cattle than does the United States. The average difference in VW trade through cattle from Canada is 3.0 billion m^3/yr (beef cattle: 2.5 Bm^3; dairy cattle: 540 Mm^3). The trend in the VWF between the two countries in trade of cattle is shown in Figure 10 and 11.

Figure 10: VWF in Beef Cattle

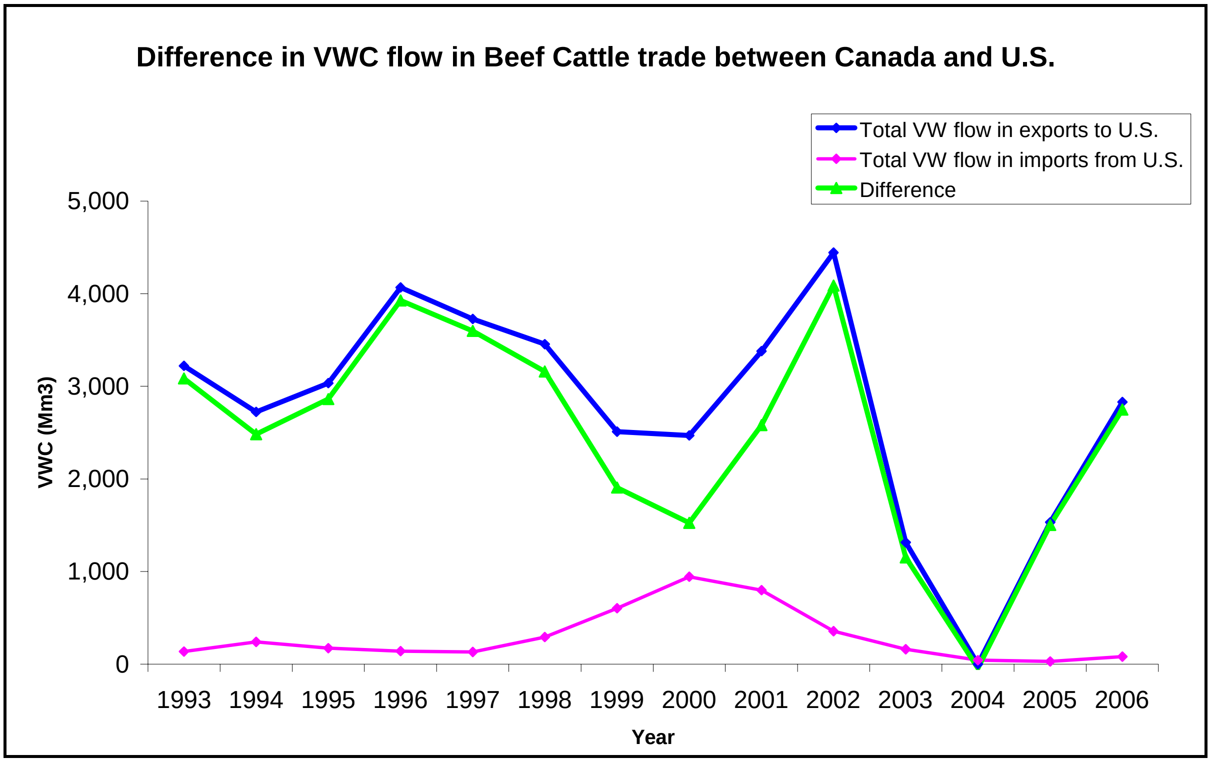
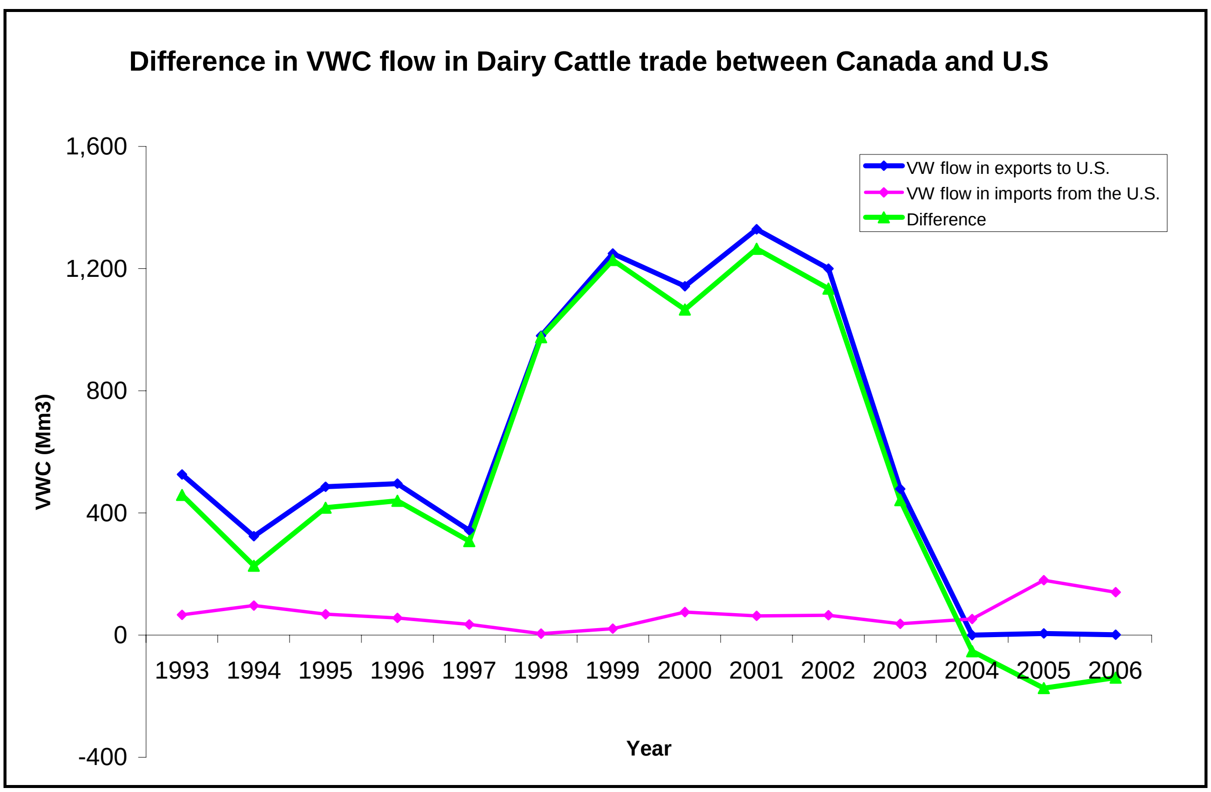


Figure 11: VWF in Dairy Cattle

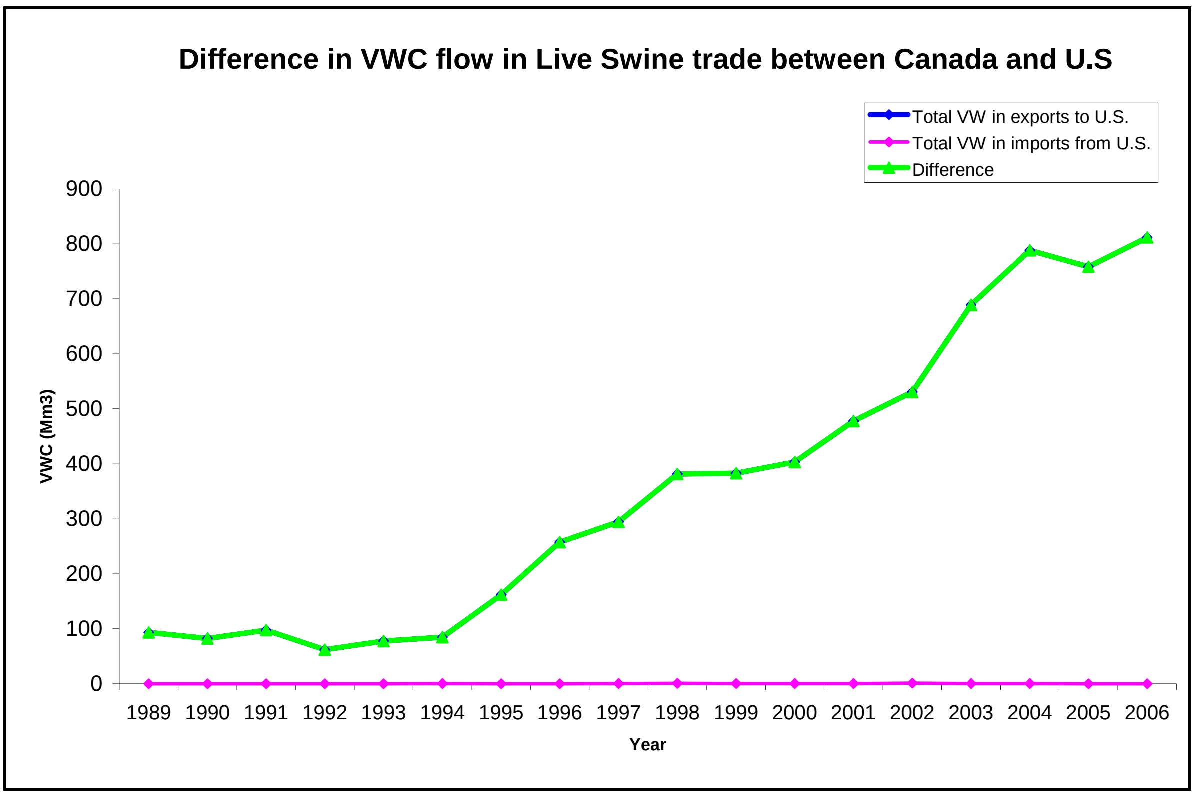


4.3.1.2 Swine

Trade in swine has increased tremendously since the signing of the NAFTA in 1994. Helped by major market re-structuring and lower Canadian dollar, the number of animals exported increased by 10 times from approximately 900,000 head to 9 million head at the end of 2006. The U.S. receives almost 100% of all Canadian swine exports and remains Canada's largest export market; but Canada imports only a fraction from the U.S. Figure 12 below is a representation of the difference in trade between the two countries.

From the VWF calculations, it can be seen that Canada on average exports 3400 times more VW than the United States. This translates to an average net difference of 440 Mm^3 of VW every year.

Figure 12: VWF in Swine



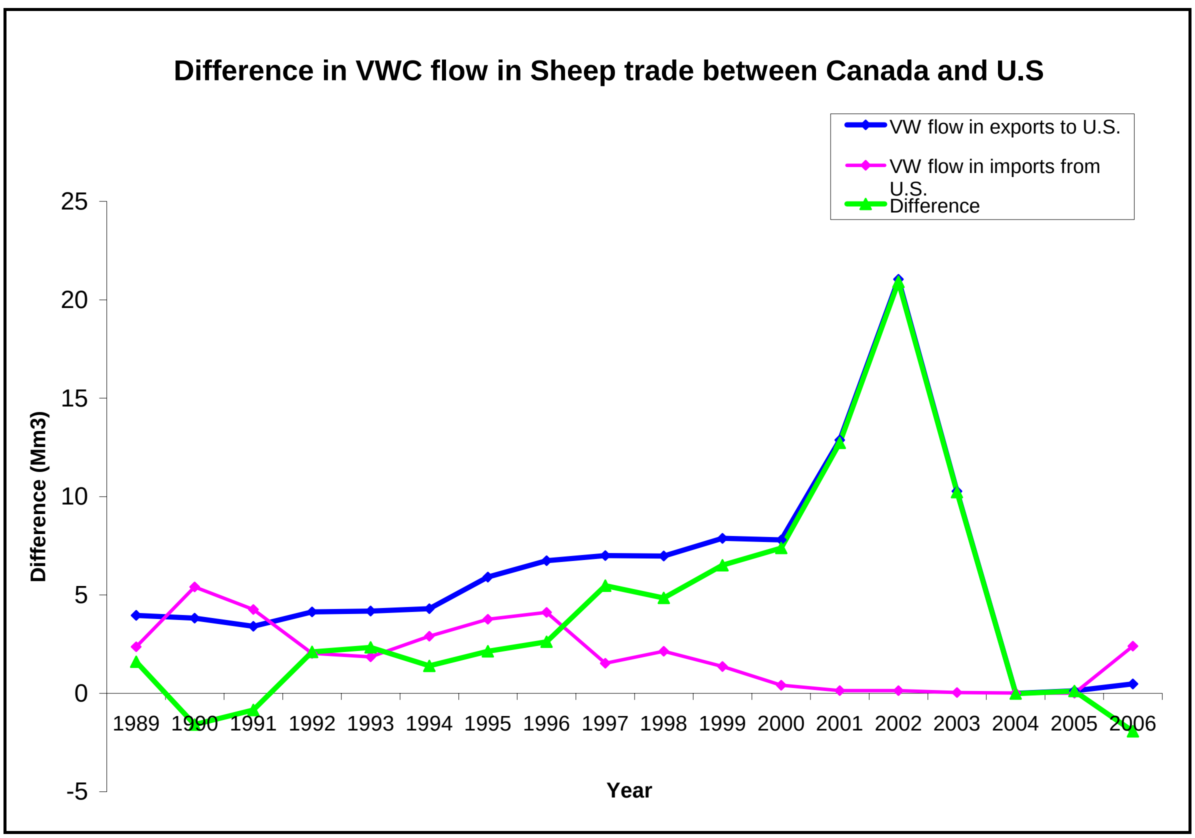
Note: Since the VW imports from the U.S. is almost zero, the line representing the difference in trade is equal to VW exports to the U.S. . Please refer to Appendix 5 for more details.

4.3.1.3 Sheep and Lamb

Trade in sheep and lamb between the two countries has fluctuated from the 1990s, but in general Canadian exports to the U.S. has prospered under the NAFTA regime. Canada exports almost 100% of its sheep and lambs to the U.S. Before the BSE trade restriction in 2003, Canada exported 139 thousand head of sheep and lamb to the U.S., a five-fold increase from number of head exported in 1994. Canada imports approximately 90% of its live sheep from the U.S. and the remaining 10% from other trading partners (Appendix 5).

Comparing the VWF between the two countries reveals that there is a difference of approximately 5 Mm^3. Canada exports 40 times more VW than the U.S. Figure 13 depicts the VWF in exports and imports and the subsequent difference in VW trade in sheep and lamb.

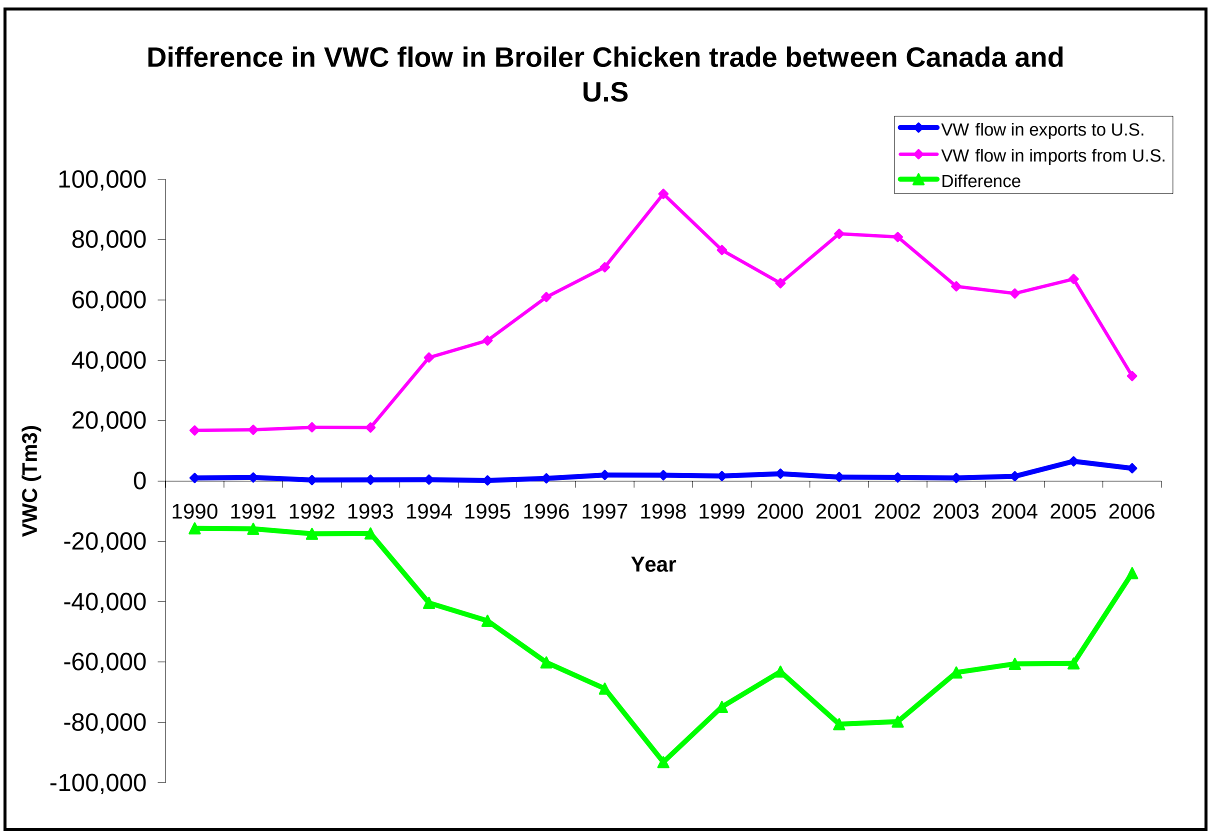
Figure 13: VWF in Sheep and Lamb



4.3.1.4 Broiler Chicken

Canada has been a net importer of broiler chicken from the U.S. even before signing of the NAFTA. However, removal of trade restrictions and obligations under WTO (see 2.2.4) has meant that the U.S. has experienced even further expansion in its trading capacities. From 1994, the number of live chicken imports from the U.S. has increased from approximately 125 thousand to 1 million in 2006. This means that the U.S. exports more VW through broiler chicken trade than Canada. Canadian deficit of VW trade is on average 54 times less than the U.S. with a difference of 50 thousand m^3/year (Figure 14).

Figure 14: VWF in Broiler Chicken

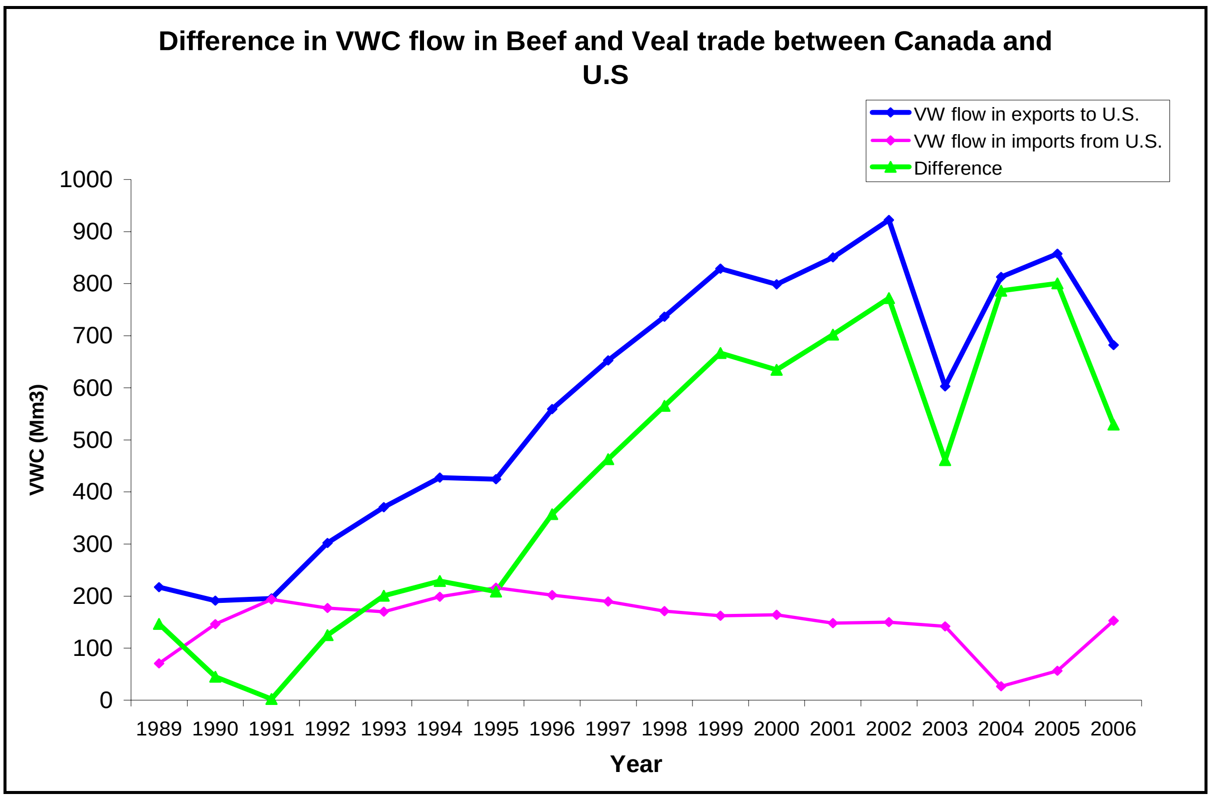


4.3.2 Trends in primary livestock product trade

4.3.2.1 Beef

Export quantity of beef to the United States has doubled since the 1990s. With imports from the U.S. remaining relatively stable, the difference in trade translates to an amount of approximately 530 Mm^3 of VW per year. Overall, Canada exports 7 times more VW than the U.S. Figure 15 shows the disparity in trade between the two countries.

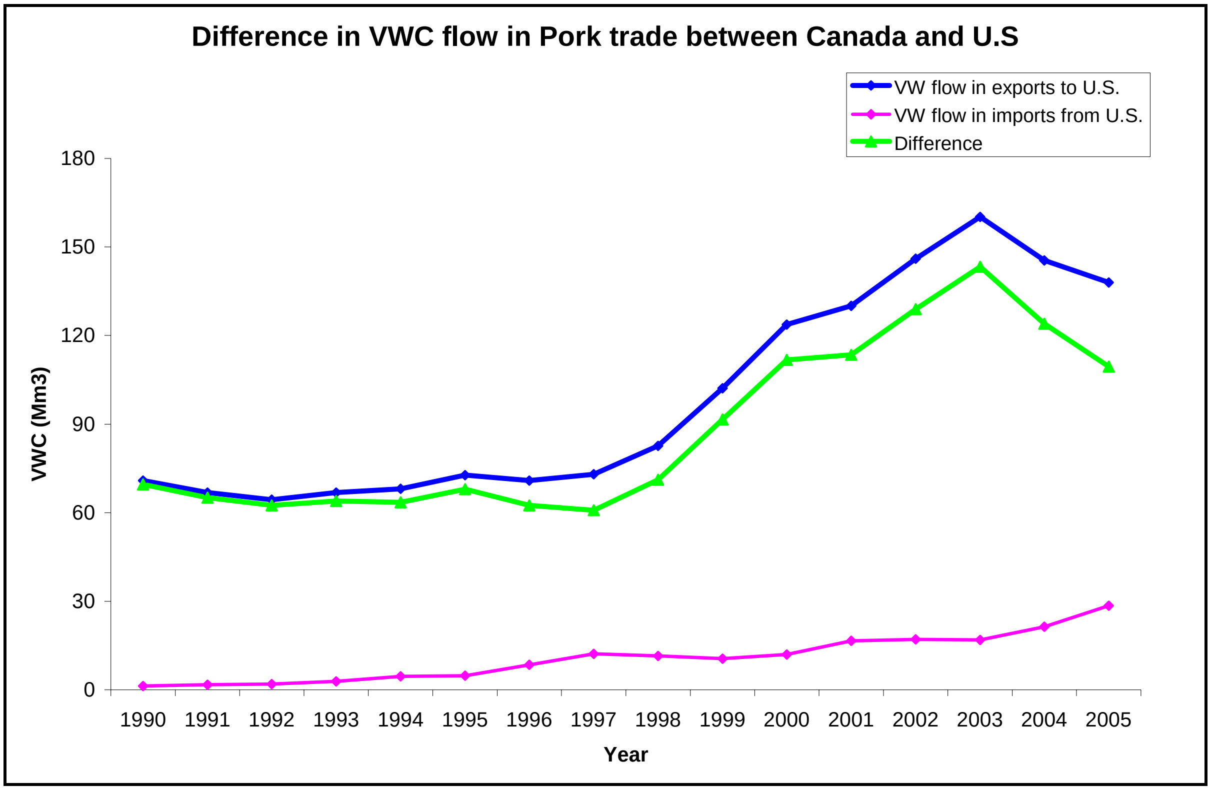
Figure 15: VWF in Beef



4.3.2.2 Pork

The export of pork to the U.S. has more than doubled under NAFTA regulations. In 1994, Canada exported 200 thousand tonnes of pork, which doubled to approximately 400 thousand tonnes in 2006 (Figure 16). The U.S. shares 56% of the Canada's export market and trades 39% of its pork with Canada. The difference in VWF in pork trade is on average 93 Mm^3/year; trade differs by a ratio of 10: 1.

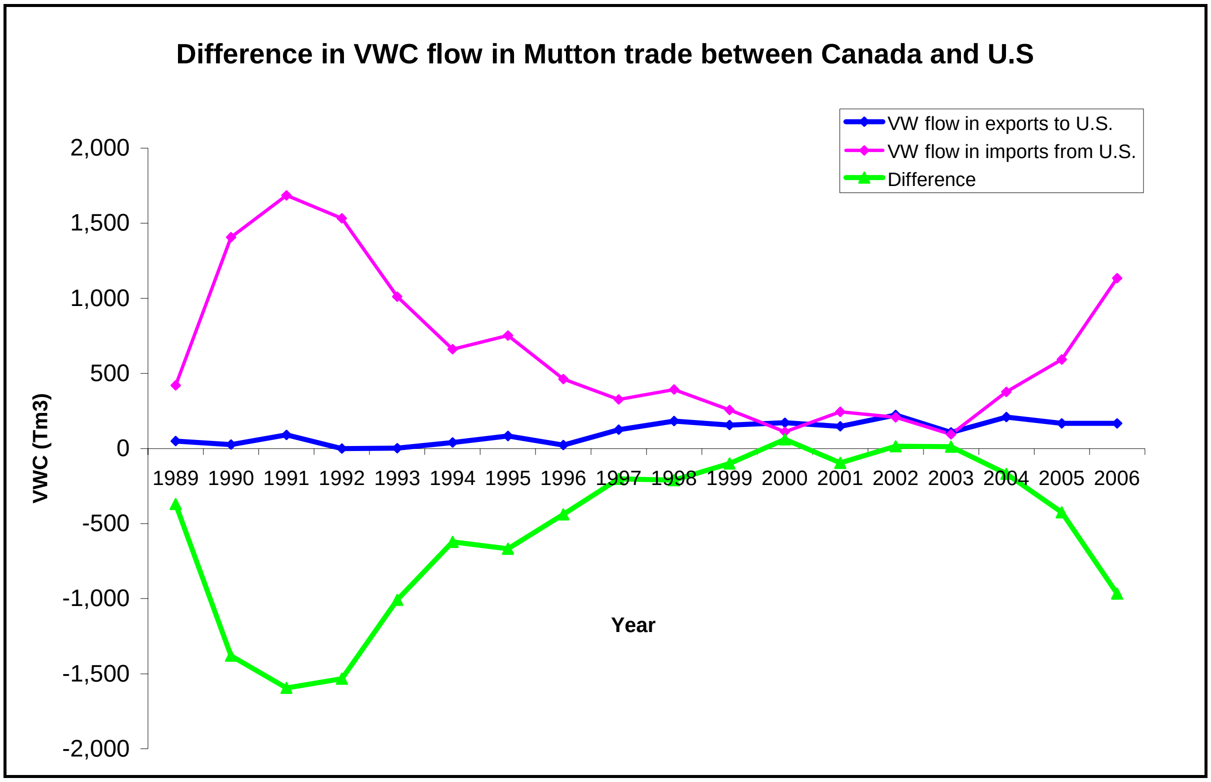
Figure 16: VWF in Pork



4.3.2.3 Mutton

Canada is a net importer of mutton, bringing in 43% of its mutton share from the United States. The United States has experienced a steady rate of decline in its mutton exports to Canada since 1991, but after 2003, its export quantity has increased exponentially. Figure 17 shows the trend in the trade of mutton between the two countries. On average, U.S. exports 31 times more VW in mutton than Canada. This is equivalent to an amount of 340Mm^3 of VW every year.

Figure 17: VWF in Mutton



4.3.2.4 Chicken Meat

Due to the unavailability of 1994-1995 trade data, data sets for Canada and U.S. were compared from 1996-2006. From the Figure 18 it is evident that trade has increased unilaterally. However, U.S. exports significantly more chicken meat than it imports from Canada. Canada's deficit in VW trade of chicken is approximately 86 Mm^3 per year.

4.3.2.5 Milk

According to the trade data in Appendix 5, exports of Canadian milk (<1% fat, 1-6% fat and >6% fat) to the U.S. has fluctuated over the years with significant reduction of trade occurring in 1993-1995. On the other hand, U.S. exports have increased exponentially since 2002 (Figure 19). The difference of VW trade in milk is on average 1600 Tm^3 per year for the period from 1993-2006; during which Canada exported 37 times more VW than the U.S.

Figure 18: VWF in Chicken Meat

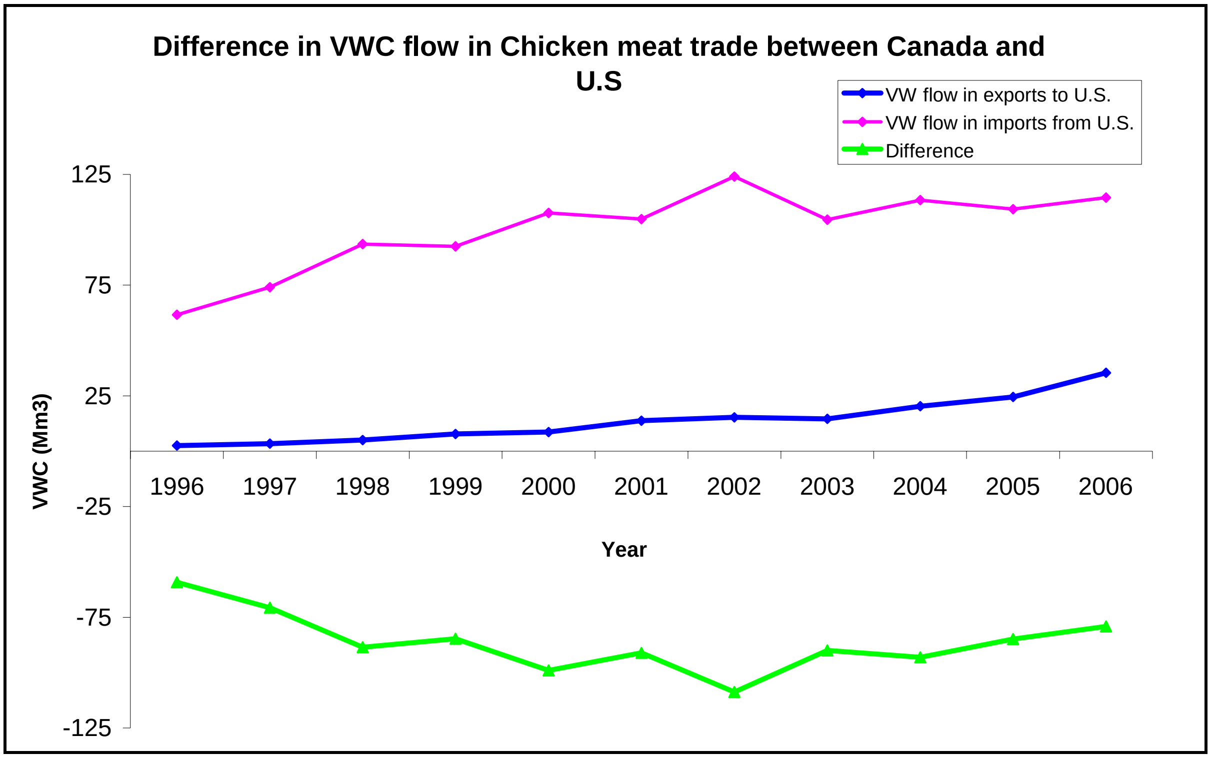
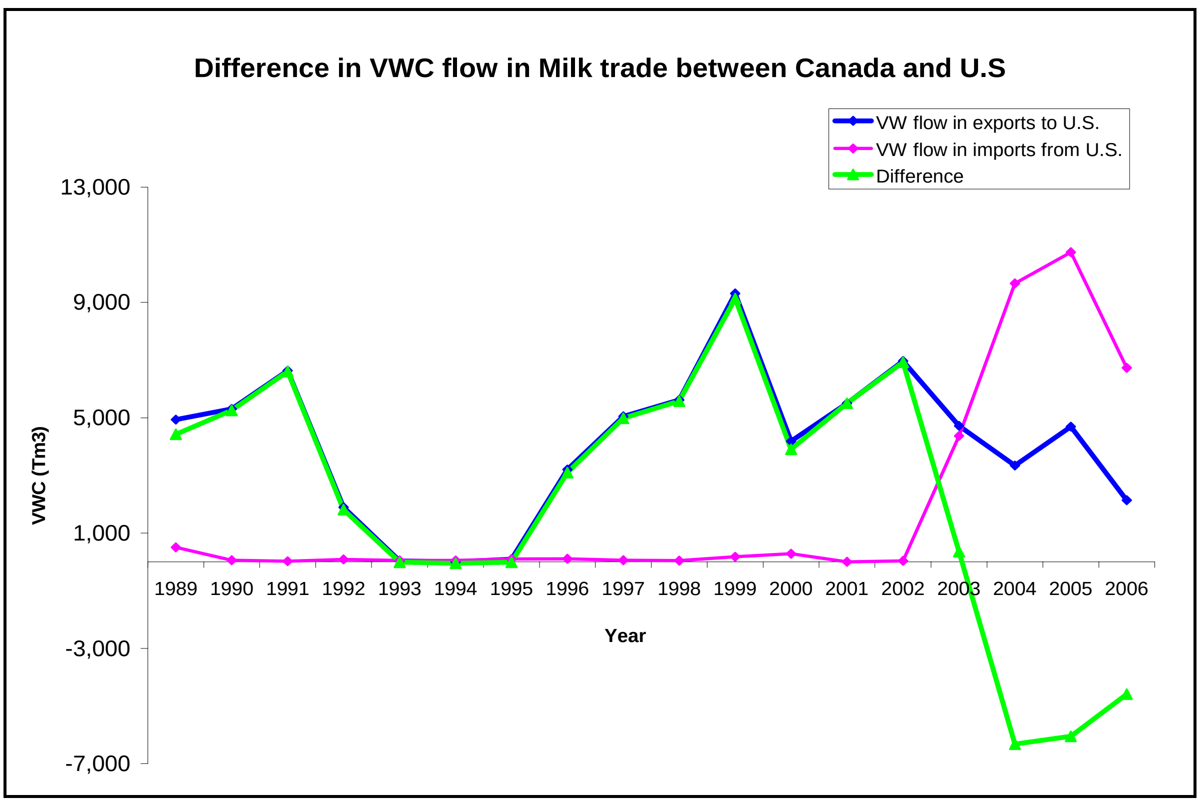


Figure 19: VWF in Milk



4.4 Summary of findings

Table 14 summarizes the findings of the virtual water flow between the two countries. It is evident that there is a large difference in the amount of VW being traded through livestock and livestock commodities. The average difference in trade has been calculated to be 3.6 billion m^3 per year. This makes Canada a net exporter of virtual water to the U.S.A. A closer look at the trade patterns and by comparing the VWC values in Table 13 reveals that Canada is involved in the export of mostly water-intensive commodities like cattle and cattle commodities while importing more of less-water intensive commodities like chicken and mutton from the U.S.

The VWF value may be an underestimate since it is an average for all years from 1993 to 2006, including those when trade was disrupted due to the BSE crisis. The value for the difference in VWF may be more if yearly values are considered.

Table 14: Comparison of average (1993-2006) virtual water export and import values for different livestock category and primary products between Canada and U.S.

Livestock Category	Avg. VW Export	Avg. VW Import	Difference	Avg. Ratio of Trade	Canada's Trade Status
	m^3	*m^3*	*m^3*		
Beef Cattle	2.7 B	30 M	+ 2.5 B	17	Small (+)
Dairy Cattle	610 M	70 M	+ 540 M	26	Small (+)
Swine	440 M	0.3 M	+ 440 M	3400	Large (+)
Sheep and Lamb	6.8 M	1.5 M	+ 5.3 M	40	Small (+)
Broiler Chicken	1.8 M	61.8 M	- 60 M	61	Large (-)
Beef	680 M	150 M	+ 530 M	7	Small (+)
Pork	106 M	13 M	+ 93 M	10	Small (+)
Mutton	129 T	470 T	- 340 T	31	Small (-)
Chicken Meat	14 M	100 M	-86 M	11	Small (-)
Milk	4 M	2.3 M	+ 1.6 M	37	Small (+)
Conclusion: Canada is a net exporter of virtual water to the United States. Overall, Canada exports more livestock and livestock commodities than it imports from the U.S. The difference in the VW trade is 3.6 billion m^3/year.					

Key:
Large: If ratio of trade > 50
Small: If ratio of trade < 50
+ : exports, - : imports

4.5 Provincial findings

For the purpose of this research, two provinces in Canada, namely Ontario and Alberta, were selected as case study regions for the VWF study. These regions were selected based on their:

- Agricultural capacities
- Expansion and specialization in a particular animal sector in the recent years
- Water concerns related to agricultural water use

A brief discussion of the water resources in the two provinces was provided in section 3.4. In a nutshell, Alberta has an annual water flow volume of 56.1 Bm^3 - out of which 158 Mm^3 was allocated for livestock and 3.9 Bm^3 for irrigation in 2005. At first glance, it may seem Alberta has self-sufficiency in water but a closer look reveals that the agricultural areas are mainly located in southern Alberta where there is severe water stress and water needs are met through the storage of water in reservoirs. Ontario, on the other hand, has abundant water supplies but this varies across the province in terms of quantity, quality and reliability. The total estimated water use in agriculture was 173.76 million cubic meter in 2001, of which livestock sector used 30%. Annual water flow volume was not available for Ontario and so the scale of the impact on its water resources could not be estimated.

Due to the insufficiency in provincial data on actual quantity of livestock and livestock products being traded with the United States, the monetary value in Canadian dollar (C$) were compared. The average ratio of the export and import values were then taken to approximate the difference in trade between the provinces and the U.S. The statistics and ratio estimation is depicted in Appendix 6 and 7. The net difference in trade and the export and import values in C$ for the two provinces were plotted in graphs to provide a visual assessment of the trade difference.

However, price data for three types of livestock, namely non-purebred beef cattle, swine and sheep were available and these were used to approximate the number of animals traded, which was then used to estimate the VWF from the provinces to the U.S. It has been assumed here that non-purebred cattle represents beef cattle, while pure-bred cattle can be both beef and dairy cattle. Hence, the VWC for dairy cattle, chicken and primary products have not been calculated in the research. Graphs for the VWF were not plotted against time to (1) maintain consistency in the presentation of data, and (2) avoid ambiguity in the research findings.

4.5.1 Alberta: Trends

The United States is the major export market for Alberta. Pre-BSE exports values shows that Alberta's trade in the livestock sector with the United States, particularly live cattle (non-purebred), swine and sheep has flourished under the NAFTA regime. In the primary products sector, beef and pork has grown exponentially. Comparing values from 1993 to 2006 in Appendix 6, it can be seen that export quantities of live swine have grown from 98 thousand head to 370 thousand head, worth approximately C$54 million. Pork exports have doubled from 1993, bringing in C$130 thousand in 2006.

Looking at the post-BSE values, it can be inferred that the province's exports of live cattle were mainly affected by the closure of international borders. The trade with the U.S. in non-purebred dropped from C$600 million in 2002 to zero in 2004. Figure 20 to 24 below depict the trend in export in these major categories. Table 15 shows the average export, import, trade difference and ratio.

Table 15: Comparison of average (1993-2006) export and import values for different livestock category and primary products between Alberta and U.S.

Livestock Category	Average Export	Average Import	Difference	Average Ratio of Trade	Alberta's Trade Status
	CAD	*CAD*	*CAD*		
Non-Purebred Cattle	530 M	31 M	+ 500 M	2500	Large (+)
Purebred Cattle	140 T	1 M	- 890 T	22	Small (-)
Swine	66 M	105 T	+ 65.6 M	1200	Large (+)
Sheep	2 M	350 T	+ 1.7 M	83	Large (+)
Broiler Chicken	180 T	510 T	- 330 T	17	Small (-)
Beef	800 T	24 T	+ 770 T	62	Large (+)
Pork	85 T	5 T	+80 T	47	Small (+)
Mutton	100 T	66 T	+ 34 T	10	Small (+)
Milk	0	43 T	- 43T	-	Small (-)
Chicken Meat	230 T	2.3 M	-2.1 M	60	Large (+)
Conclusion: Alberta is a net exporter of virtual water to the United States. Overall, Alberta exports more livestock and livestock commodities than what it imports from the United States in monetary value (Difference: 560 million CAD).					

Key:
Large: If ratio of trade > 50
Small: If ratio of trade < 50
+ : exports, - : imports

From the table it can be seen that on average Alberta exports 2500 times more cattle that are non-purebred and 1200 times more swine than the U.S. Imports mainly include purebred cattle and chicken meat. However, the imports of purebred cattle have declined significantly in the past several years (Figure 21). It can be concluded that, Alberta is a net exporter of virtual water to the United States. Overall, Alberta exports more livestock and livestock commodities than it imports from the United States in monetary value (Difference: 560 million CAD). Using Equation 7 (pg. 65), the VWC was approximated for the non-purebred, swine and sheep. Other categories could not be calculated due to the unavailability of quantitative price data. As per calculations (Table 02 in Appendix 6) Alberta exports virtual water in a net difference of 1.3 billion m^3 in non-purebred cattle, 37 million m^3 in swine and 2.9 million m^3 in sheep.

Figure 20: Alberta's trade balance in Non-purebred Cattle with the U.S.

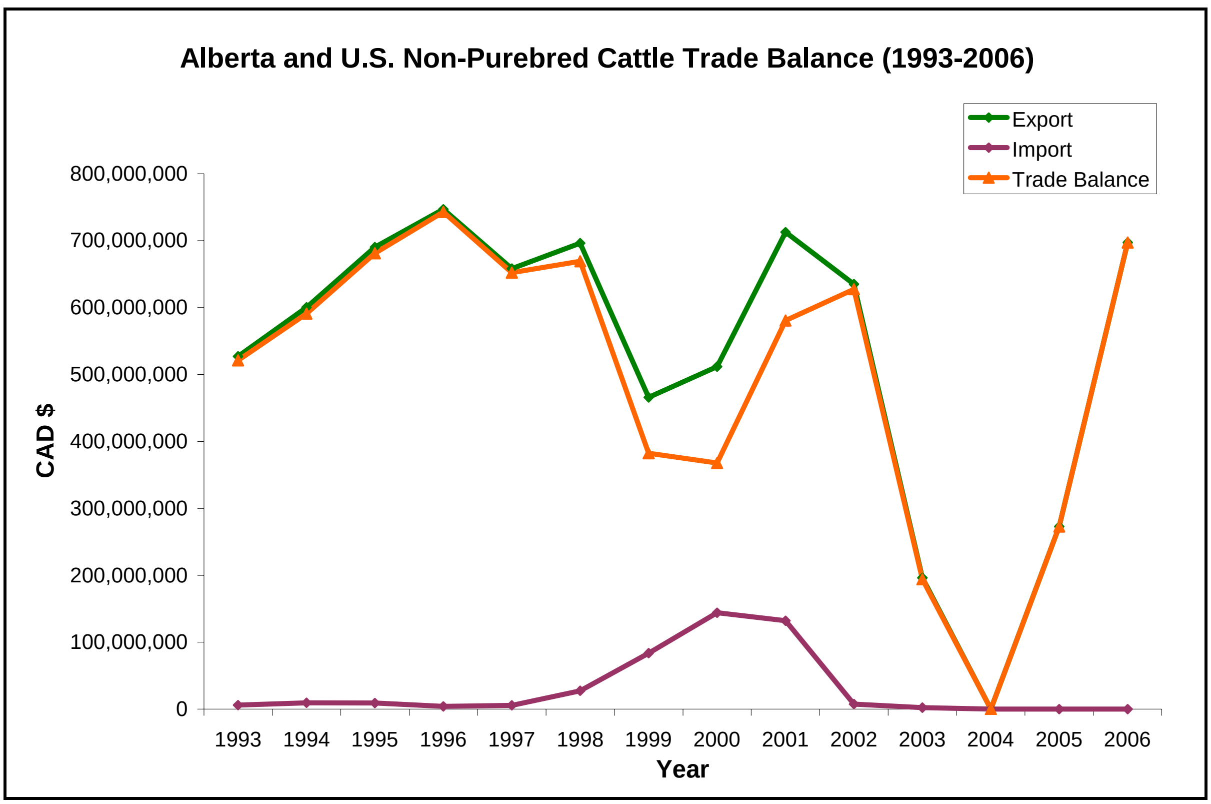


Figure 21: Alberta's trade balance in Pure Bred Cattle with the U.S.

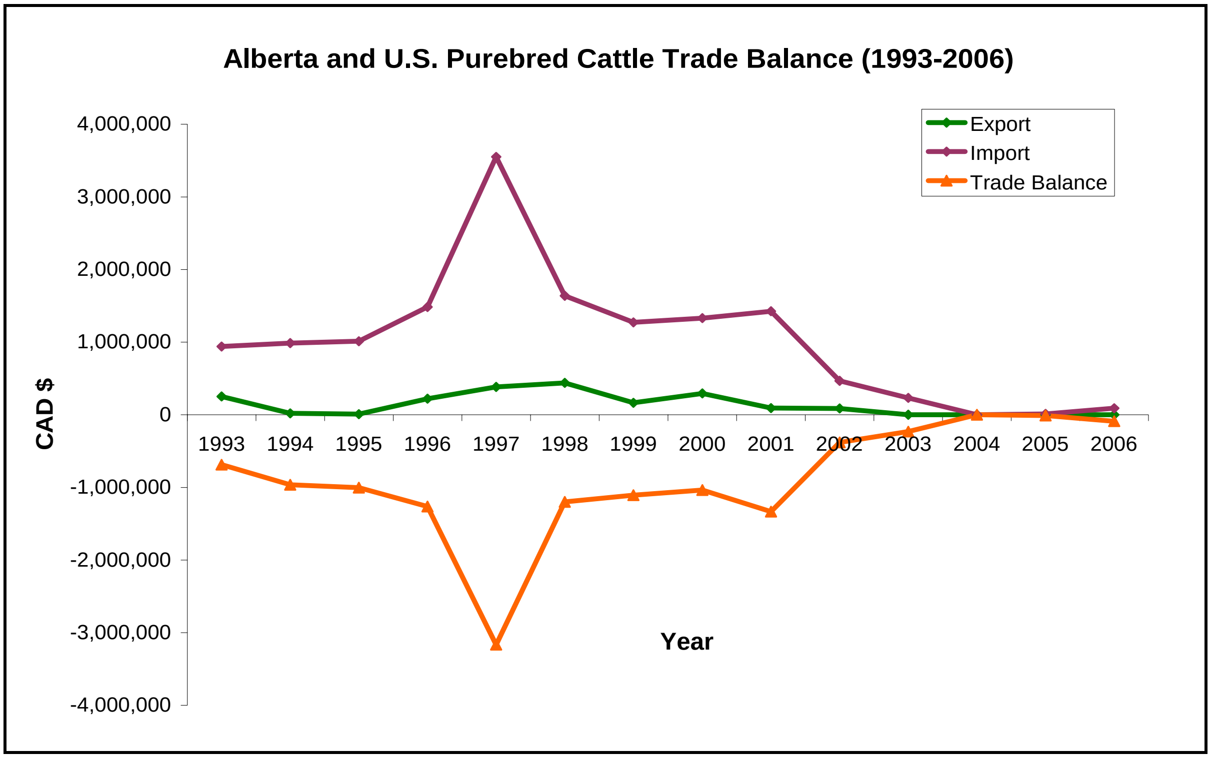
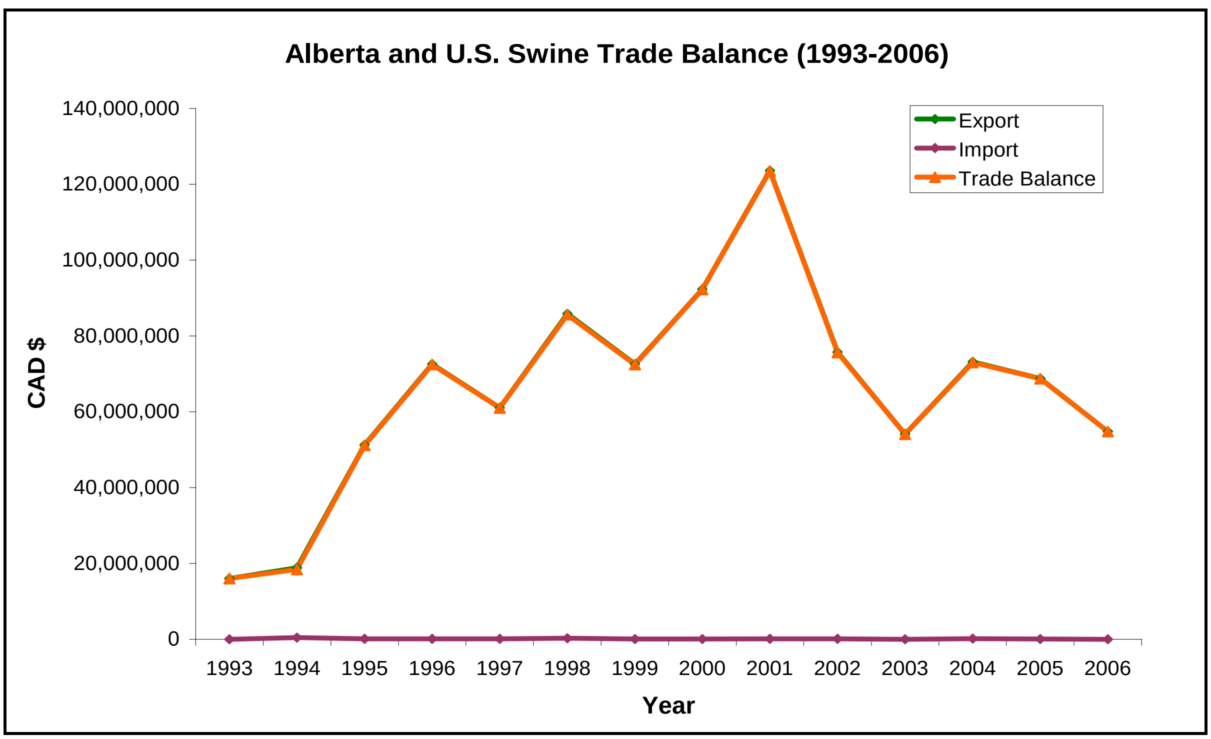


Figure 22: Alberta's trade balance in Swine with the U.S.



Note (Figure 22): Since the imports from the U.S. is almost zero, the line representing the difference in trade is equal to exports to the U.S. Please refer to Appendix 6 for more details.

Figure 23: Alberta's trade balance in Beef and veal with the U.S.

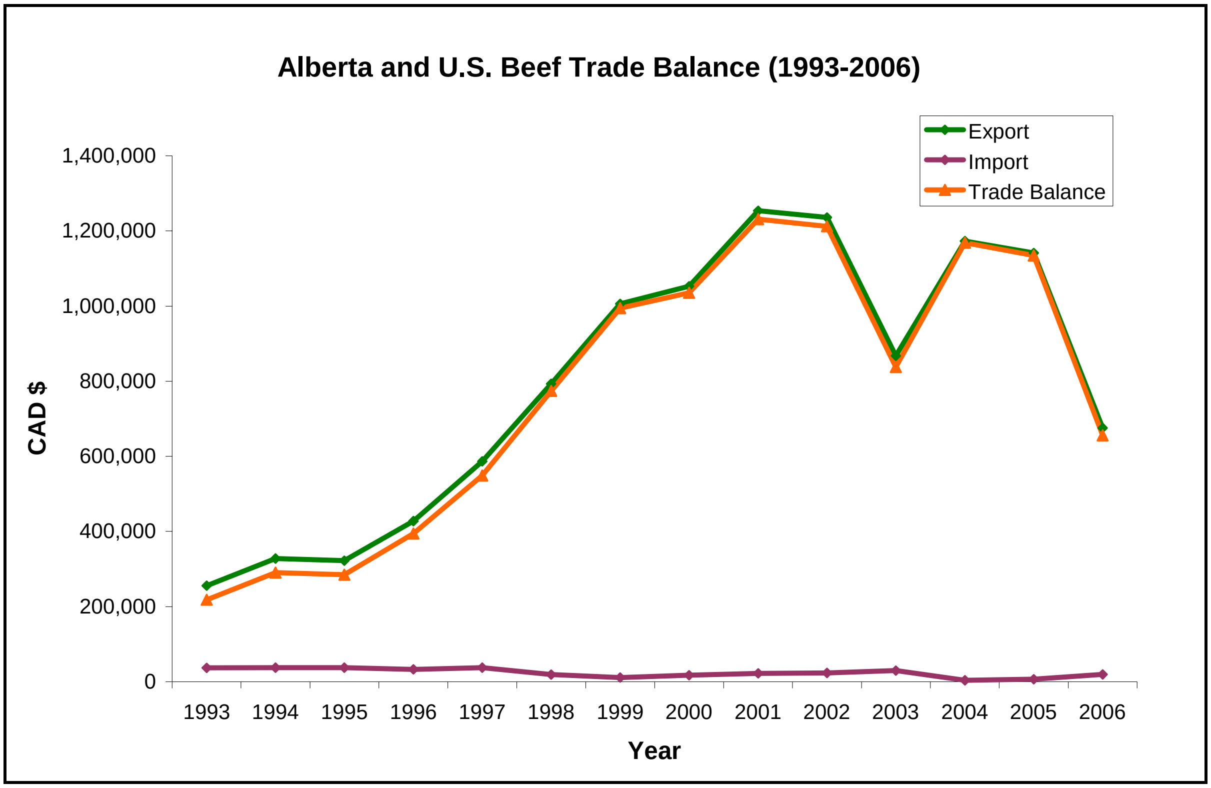
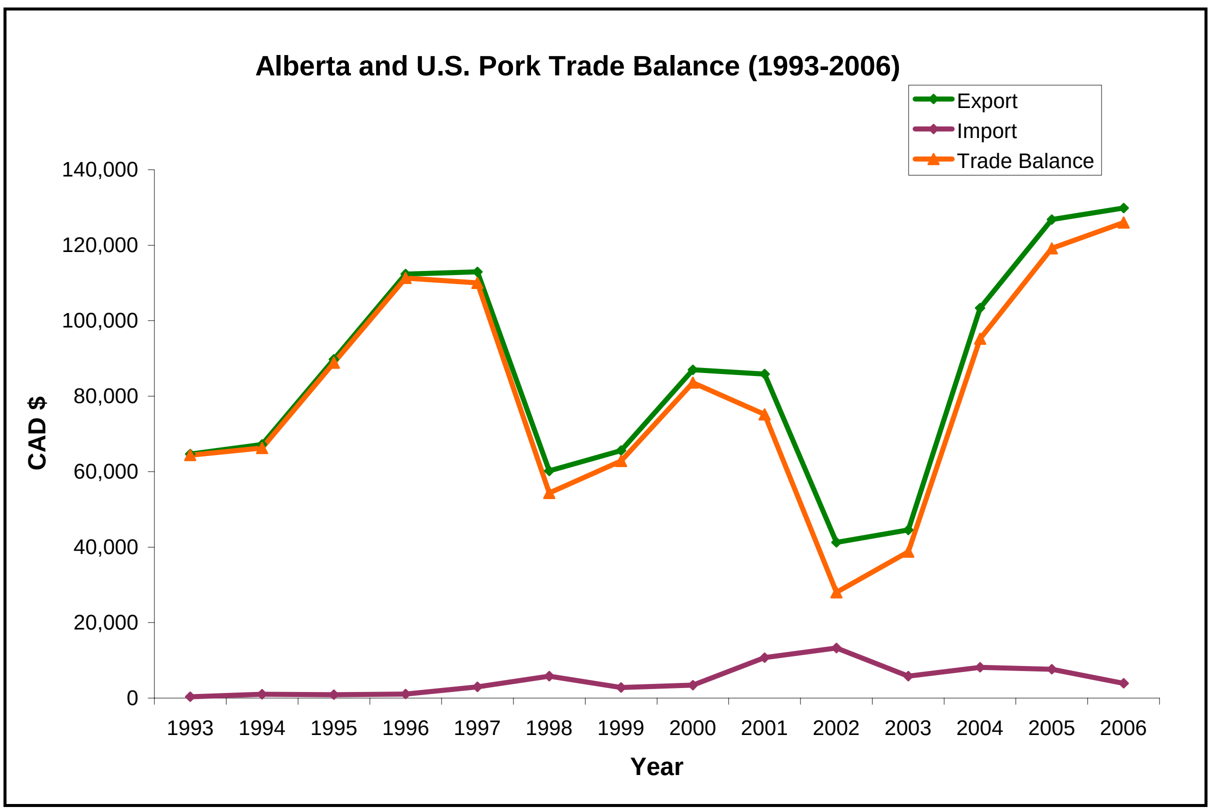


Figure 24: Alberta's trade balance in Pork with the U.S.



4.5.2 Ontario: Trends

The United States is Ontario's export market for live swine and pork. From the initiation of NAFTA in 1994, export quantities of live swine has grown from 170 thousand head to 1.3 million head in 2006, worth a value of approximately C$190 million. Pork exports have grown three-fold from 1993, bringing in C$280 thousand in 2006. Ontario also exports both pure and non-purebred cattle to the U.S., but this trade has been badly affected during the BSE trade restriction years from 2003-2005. In 2002, Ontario exported 290 thousand head of non-purebred cattle for C$340 million, compared to 1993, when it exported only 125 thousand head. Exports of purebred cattle also saw a substantial increase from C$1.3 million to C$10 million during the same time.

Trade of sheep and mutton has fluctuated over the years, with the U.S. dominating trade after 2003. The U.S. exports mainly chicken, chicken meat and beef to Ontario. From 1993, import values of chicken meat has increased from C$10 thousand to C$250 thousand in 2006. Figure 25 to 29 below depict the trend in export in these major categories; Table 16 shows the average export, import, trade difference and ratio.

Table 16: Comparison of average (1993-2006) export and import values for different livestock category and primary products between Ontario and U.S.

Livestock Category	Average Export	Average Import	Difference	Average Ratio of Trade	Ontario's Trade Status
	CAD	*CAD*	*CAD*		
Non-Purebred Cattle	164 M	24 M	+ 140 M	9	Small (+)
Purebred Cattle	3.6 M	510 T	+ 3.1 M	9	Small (+)
Swine	140 M	90 T	+ 140 M	3200	Large (+)
Sheep	570 T	640 T	- 60 T	10	Small (-)
Broiler Chicken	3 M	15 M	- 12 M	10	Small (-)
Beef	190 T	240 T	- 51 T	2	Small (-)
Pork	182 T	92 T	90 T	3	Small (+)
Mutton	850 T	1 M	- 260 T	34	Small (-)
Milk	970 T	1 M	- 45 T	1100	Large (+)
Chicken Meat	15 T	200 T	- 180 T	23	Small (-)
Conclusion: Ontario is a net exporter of virtual water in swine and a net importer in mutton, chicken and chicken meat. Overall, Ontario exports more livestock and livestock commodities than it imports from the United States in monetary value (Difference: 270 million CAD).					

Key:
Large: If ratio of trade > 50
Small: If ratio of trade < 50
+ : exports, - : imports

From the table it can be seen that on average Ontario exports 3200 times more swine, 1100 times more milk and 9 times more non-purebred cattle than the U.S. On the other hand, the U.S. exports 34 times more mutton, 23 times more chicken meat and 10 times more sheep to Ontario. Based on the ratio of trade, it can be concluded that Ontario is a net exporter of virtual water in swine and a net importer in mutton, chicken and chicken meat. Overall, Ontario exports more livestock and livestock commodities than it imports from the United States in monetary value (Difference: 270 million CAD).Using the Equation 7 and 8 (pg. 65), the VWC was approximated for the non-purebred, swine and sheep. As per calculations (Table 2 in Appendix 7) Ontario exports virtual water in a net difference of 320 million m^3 in non-purebred cattle; 77 million m^3 in swine and has a deficit of 37 thousand m^3 in sheep.

Figure 25: Ontario's trade balance in Non-Purebred Cattle with the U.S.

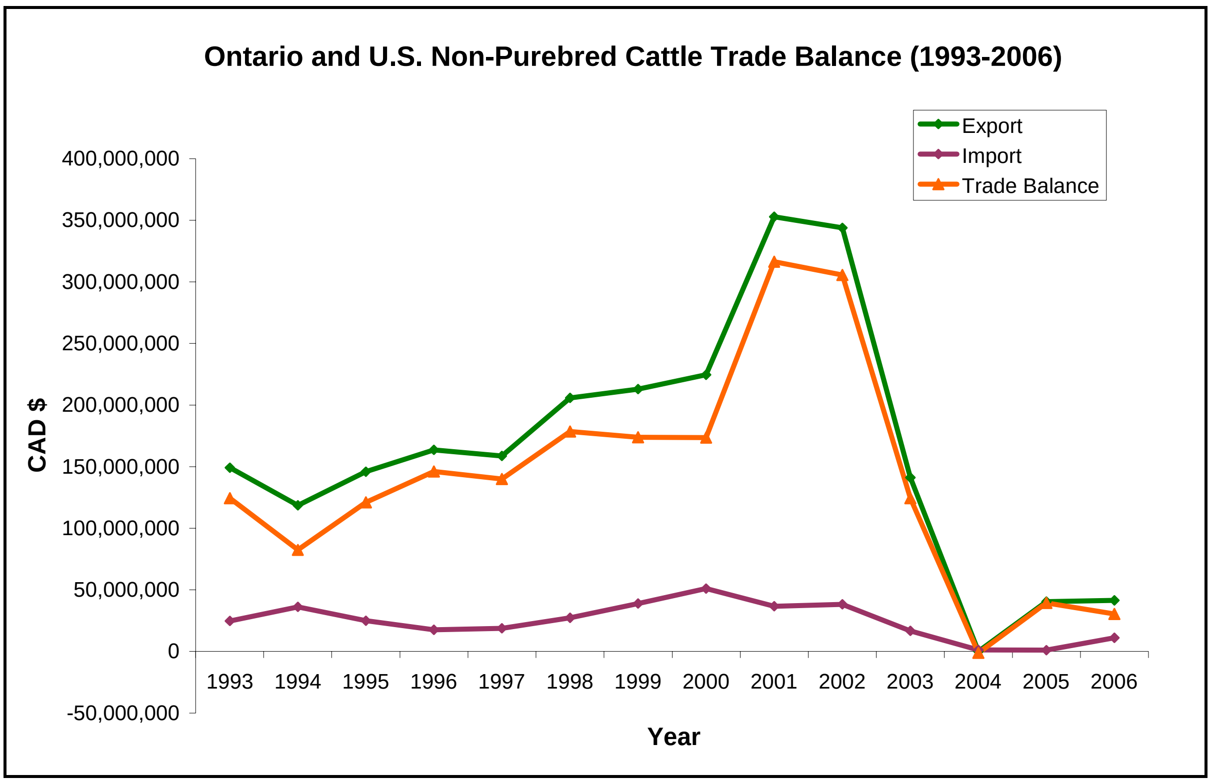


Figure 26: Ontario's trade balance in Purebred Cattle with the U.S.

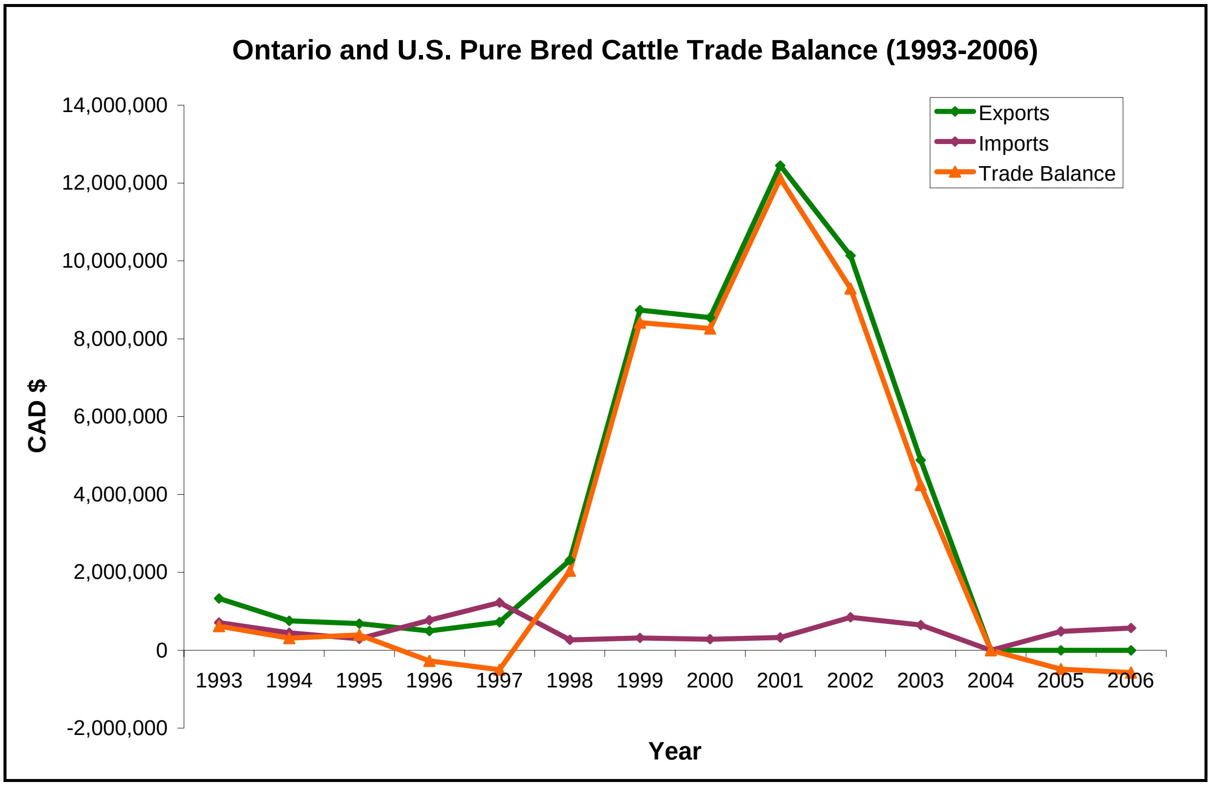


Figure 27: Ontario's trade balance in Swine with the U.S.

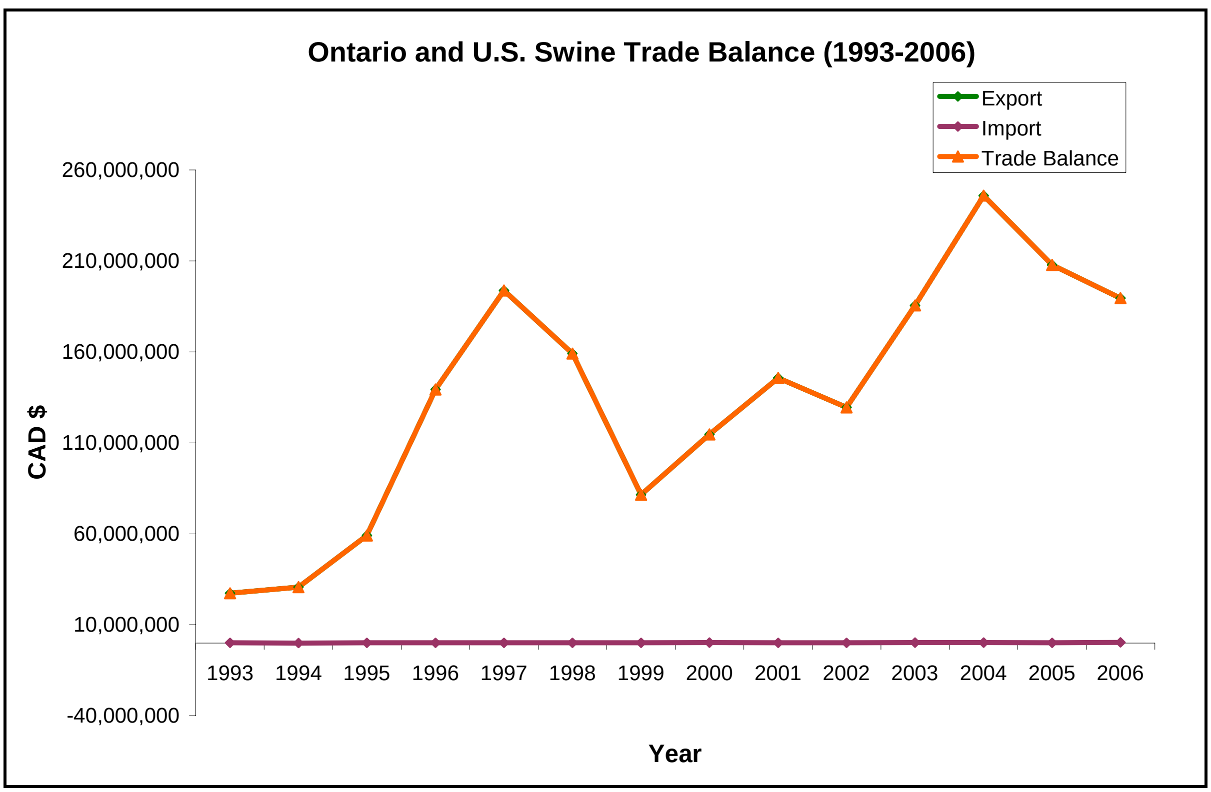


Figure 28: Ontario's trade balance in Pork with the U.S.

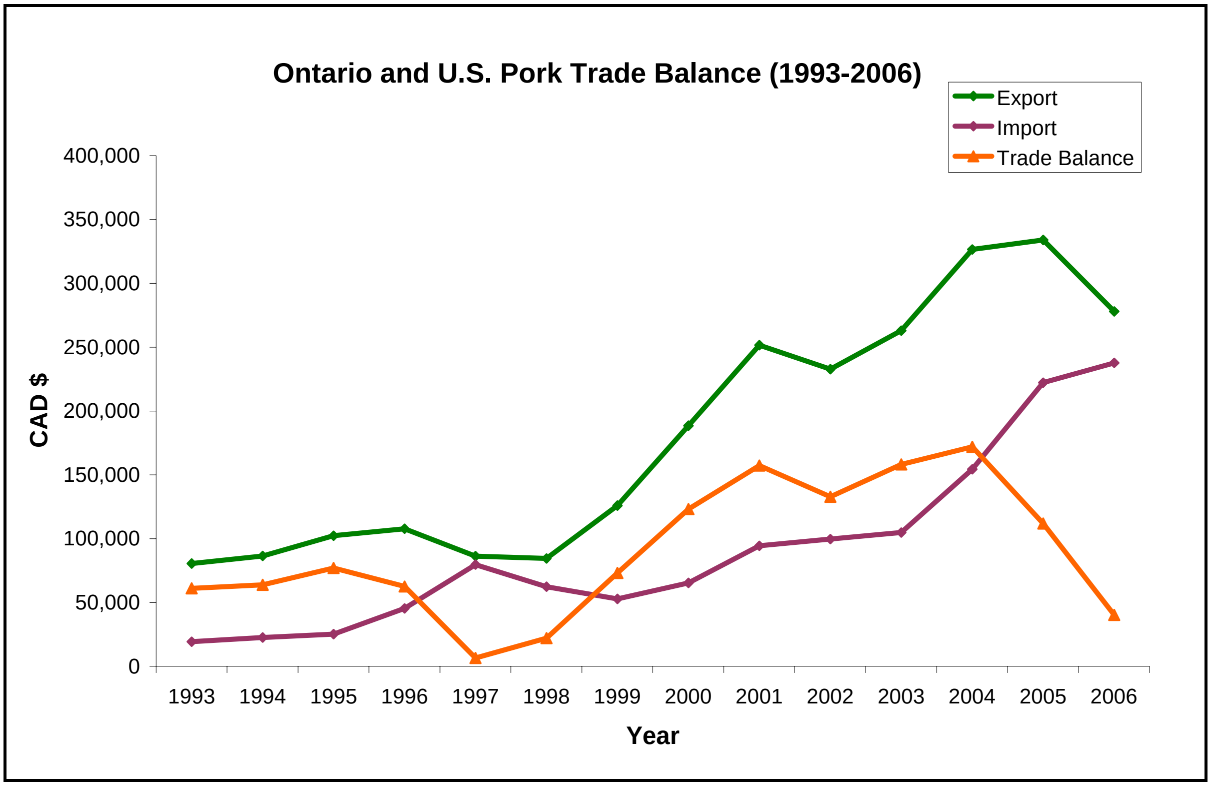
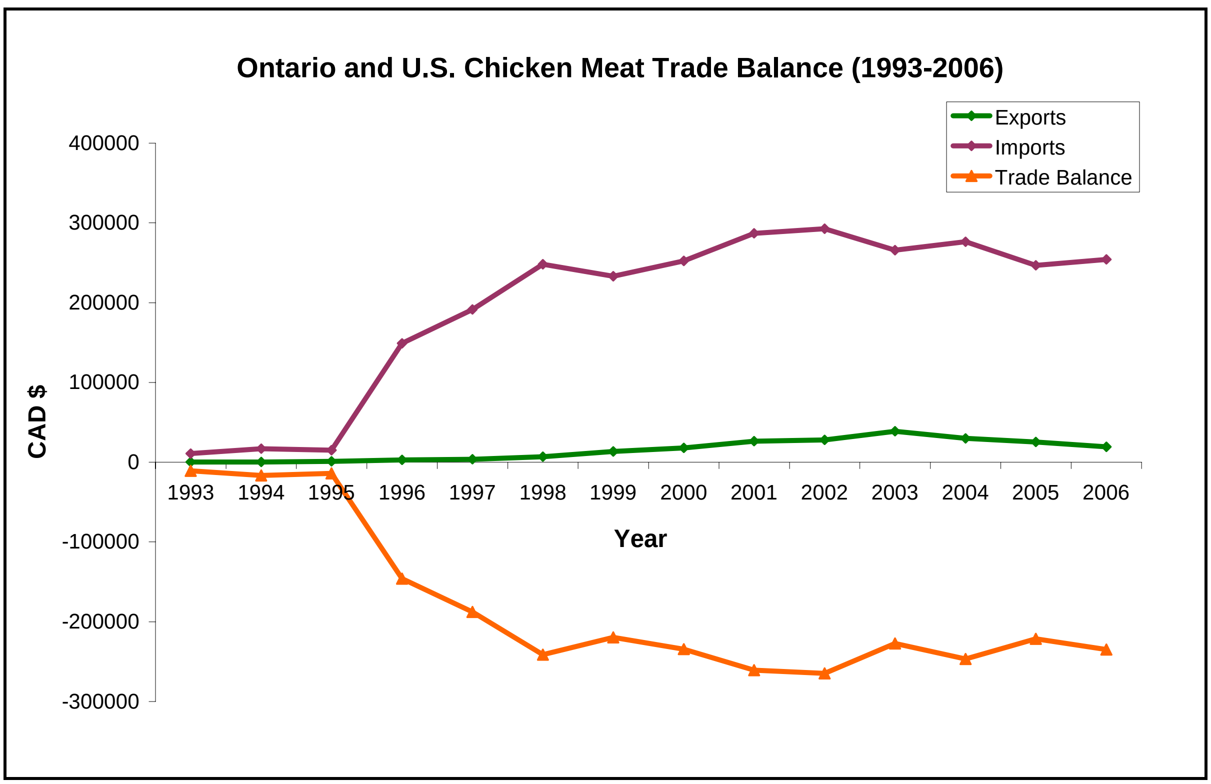


Figure 29: Ontario's trade balance in Chicken Meat with the U.S.



4.6 Conclusion

This chapter highlighted the research findings on the virtual water content of different livestock and livestock products. It also summarized the results from the virtual water flow calculations for Canada and the two case study areas: Alberta and Ontario. Graphs were also provided to better understand the outcome of the research. From the calculations, it can be noted that Canada is a net exporter of virtual water in livestock commodities to the United States. The large difference in the amount of VW traded calls for further discussion on the overall impact of NAFTA on the water resources of Canada.

5 Discussion

5.1 Introduction

As trade flourishes between Canada and the U.S. under the NAFTA regime, it has become increasingly important to investigate the hidden environmental implications of this trade liberalization. The virtual water concept is a new concept and has been used in this research to investigate the impact of trade of livestock and livestock products on Canadian water resources. The primary question that shaped the focus of this research was:

How much virtual water is being traded through livestock and livestock products between Canada and the United States and what implications does this trade have on Canadian water resources?

Four secondary questions were the basis to answer the research question:

1. *How has NAFTA affected Canada-U.S. trade relations?*
2. *How has the trade in livestock and livestock products changed from pre-to-post NAFTA?*
3. *What is the net balance of virtual water being traded between the two countries in the livestock sector?*
4. *What are the implications of the U.S.-Canada meat trade on water resources of Canada?*

This chapter provides a summary of the research findings in light of the primary and four secondary research questions explored. It then provides an analysis of the position of virtual water within the NAFTA framework.

5.2 Re-exploring the research questions

The North American Free Trade Agreement sets forth a schedule for the gradual phasing out of tariffs and the elimination of barriers with the main goal of expanding trade and investment among Canada, the United States and Mexico. While the NAFTA does not contain a separate section dealing with American-Canadian agricultural trade, it does incorporate as number of agricultural trade provisions from the Canada-U.S. Free Trade Agreement. Under the CUSFTA, most agricultural tariffs between the U.S. and Canada were to be phased out by January 1998, and NAFTA adopted this schedule.

As has been seen in the course of this research, the implementation of the Canada-U.S. Free Trade Agreement (CUSFTA) and North American Free Trade Agreement (NAFTA) saw the Canadian agricultural trade with the U.S. grow in size and importance. By eliminating numerous trade barriers, the agreement has allowed competitive market forces to play a more dominant role in determining agricultural trade flows between the two countries. Although other factors such as weather conditions, population growth, technological competitiveness, market exchange rate and macroeconomic performance have all contributed to the increase in Canadian agricultural trade, there is nonetheless no denying that NAFTA has acted as a catalyst for increasing the agricultural trade between the two countries. The U.S. remains Canada’s largest trading partner, accounting for over 60% of Canada's total agriculture and agri-food export sales in 2005 compared with a 40% share in 1990 (Statistics Canada, 2007a).

Table 17: Percentage change in export quantity of Canada’s major livestock products to the United States

Product	Unit	1993	2002	2006	% change
			Pre-BSE	Post-BSE	1993-2002
Primary					
Beef Cattle	head	1,172,400	1,618,200	1,030,900	38
Dairy Cattle	head	29,900	68,200	73	128
Sheep and Lamb	head	27,600	139,000	3,120	404
Swine	head	837,800	5,738,000	8,763,000	585
Secondary					
Beef and Veal	tonnes	164,700	409,600	302,900	149
Milk	litres	43,200	7,953,000	2,445,000	18310
Pork	tonnes	188,100	411,100	388,500*	119

* values are for 2005

The agricultural sector that has shown the greatest increase in trade flows to the U.S. has been the livestock sector (Ash, 2005). Table 17 summarizes the trade pattern before and after the signing of the NAFTA. If values of 1993 are compared with that of pre-BSE values, it can be seen that there has been an increase in almost every livestock category, with considerable increases in sheep, swine and milk trade. Although intra-industry trade in all categories has increased between the two countries, Canada's export has been significantly more than the U.S.'s export to Canada. This discrepancy has been indicated in Table 14 in the *Research Findings* chapter.

Having established the trend in livestock and livestock commodity trade, the research moved on to examine the difference in virtual water transfer between the two countries. Based on the model developed by Chapagain & Hoekstra (2003), the virtual water content of the different livestock categories was estimated and used to extrapolate the virtual water transfers between the two countries and the difference in virtual water trade. On average there is a difference of ***3.6 billion*** $\boldsymbol{m^3}$ of virtual water flowing from Canada to the U.S. every year in the trade of livestock and livestock commodities alone. This trade is occurring from regions which can ill afford the loss of water (Alberta).

The NAFTA-water and NAFTA-environment debate has been in the media spotlight since the inception of the agreement in 1994. The Council of Canadians has repeatedly declared Chapter 11 as being unconstitutional because it allows corporations to override the public laws of a country (Barlow, 2005). It claims that the Chapter 11 process does not use the court system — cases are dealt with in secrecy using independent arbitrators. Moreover, the terms of the agreement have compromised Canada's sovereignty over water resources by allowing the U.S. the capacity to import bulk water from Canada. Environmental standards are also stimulating a debate among the Democratic Party candidates in the 2008 U.S. presidential race. Both Hillary Clinton and Barack Obama have publicly stated a desire to pull out of NAFTA if certain terms are not renegotiated. Chief among their concerns are environmental standards and practices, as well as pulling out of the controversial Chapter 11.

If virtual water is taken to be the amount of water required to produce an agricultural commodity, then the water has already been converted into a product and is subject to NAFTA (Article 201-definition of goods of a party) and GATT (HS Code 22.01.9 - all natural water other than sea water) provisions. Although, virtual water has not been part of the contentious water-NAFTA debate, it is however important to highlight the criticisms set by Holm, Barlow and others about how NAFTA is exploiting the water resources of Canada. By establishing a free trade zone between Canada and the U.S., NAFTA has facilitated the trade in water embedded in agricultural commodities. The U.S. may not require large diversions or engineered systems to access Canadian freshwater. However, they are subsidizing their agricultural water needs by importing water intensive commodities from Canada.

The social and environmental effects of agricultural trade under NAFTA have been investigated by many scholars (Chiu, 2003; Duncan, 2003; Vaughan, 2004). Most negative externalities associated with agriculture are believed to be the common air, water and land pollution scenarios and effects on communities and populations. However, no major research has investigated other forms of externalities, such as the virtual water transfer in agricultural commodities between two nations and its impacts on the exporting country. There is a need to assess Canada's costs and benefits of this free trade, in terms of water loss and savings.

In the context of this research, a simple way to assess the impact of NAFTA on water resources is to break down the effect of trade liberalization into "scale, technique and composition effects" (Antweiler et al., 2001; Copeland & Taylor, 1994). The *scale effect* theory states that free trade causes increased output and scale of production which may have negative environmental effects, as it generates additional pollution emissions and accelerates the depletion of natural resources. The *composition effect* identifies the change of goods production as a result of freer trade — resources formerly devoted to protect inefficient industries are utilized elsewhere hence altering the incidence, type and level of environmental degradation. The *technique effect* explains the tendency for higher income nations to value cleaner environments. Trade liberalization increases per capita incomes, and therefore results in greater pressure on producers to alter production methods to adopt cleaner production technologies.

Although the *technique effect* of NAFTA was not analyzed in this research, the VW calculations clearly point to a negative *scale* and *composition effect* on Canadian water resources. As is indicated in Appendix 3, the *scale* of livestock production has increased manifold. This increase has been achieved by the intensification of production of certain categories of livestock in different parts of Canada. This intensification is a result of *composition* effects brought about by structural and policy reforms in the livestock sector under NAFTA.

There is no doubt that Canada has benefited economically from the free trade pact. However, the agricultural effect on its water resources have been overlooked. Increased pressure to produce more livestock has forced framers to intensive livestock production patterns. These operations are an extremely water-intensive processes. For Alberta, most of livestock production is concentrated in the south where there is water scarcity. Water demands for agriculture are met by reservoirs which capture and store water. According to Alberta Agriculture, Food and Rural Development (2004), the replacement value of the irrigation district infrastructure was estimated to be $2.5 billion dollars in 2003. For Ontario, localized droughts have been reported almost every year somewhere in the province from 1960 and this has caused serious problems for farmers in some regions who are reliant on large quantities of water. The economic implications of drought have been tremendous with crop insurance payments increasing from $55 million in 1988 to $244 million in 2001 (de Loë et al., 2001).

For Alberta, the VW required in the production of beef cattle increased from 4.5 Bm^3 in 1991 to 5.8 Bm^3 in 2001. If the annual flow of water in Alberta is 56.1 Bm^3/year, then the production of beef cattle constitutes 10% of the total water available in Alberta. This is a significant portion of the water being used for the production of only one type of agricultural commodity. For Ontario, swine production has seen a transformation under NAFTA. The VW requirement for production of swine increased almost 19% in a decade. Table 18 below summarizes Ontario and Alberta's change in VW requirements in the production of different animal categories from 1991 to 2001.

Table 18: Change in scale of livestock production and associated VW requirement changes from 1991-2001

Category	Alberta		Ontario		Alberta		Ontario	
	1991	2001	1991	2001	1991	2001	1991	2001
	No. of animals				VWC (m^3)			
Beef cattle	1,635,727	2,099,288	389,659	376,020	4.5 B	5.8 B	1.1 B	1.0 B
Dairy cattle	105,905	84,044	442,996	363,544	1.8 B	1.5 B	7.8 B	6.4 B
Swine	1,729,870	2,027,533	2,924,936	3,457,346	160 M	190 M	270 M	320 M
Sheep	305,642	307,302	251,620	337,625	46 M	46.5 M	38 M	51 M

In order to internalize the external costs to water resources due to the increase in trade, it is suggested that the price of commodities reflect this hidden cost. Some critics of neoclassical orthodoxy, commonly known as the 'social greens' or 'bioenvironmentalists' (Clapp & Dauvergne, 2005), propose that trading countries should adopt the same rules of cost internalization, and necessitate compensatory tariffs (protection) during period of negotiation to harmonize rules of environmental protection (see Daly & Goodland, 1994; Krugman, 1997). However, this approach is not easily attainable among sovereign states with different priorities and resources, and at different stages of development (Daly & Goodland, 1994; Johnson & Beaulieu, 1996; Kirton, 2002).

5.3 Inclusion of Virtual Water in the NAFTA environment/water debate

Agriculture is and will continue to be a major contributor to environmental degradation, inducing the conversion of natural ecosystems to agricultural production as the sector responds to increased demand for food and fibres due to increases in population and wealth. As has been seen in the course of this research, agricultural goods comprise an important segment of international commodities trade and there can be negative environmental effects from increased agricultural trade. The calculations of the virtual water transfer between Canada and the United States revealed that there is a large difference of ***3.6 billion*** m^3 of virtual water every year in the trade of livestock and livestock commodities. Given this trade difference, it becomes pertinent to investigate the position of virtual water in the provisions (general or environmental) of NAFTA. Do environmental provisions apply to virtual water? Can the evidence posed by virtual water calculations be sufficient to illustrate resource exploitation and over utilization of the water resources for agricultural trade? Does the NAFTA realize claims based on the VW estimations? Or, is it all arbitrary?

Looking back to the discussion in section 2.4.3 of the NAFTA chapter — the Canadian government (at the height of the water NAFTA debate) had included wording to prevent the NAFTA from applying to water policy in its Implementation Act. This change explicitly exempted water in its natural state from provisions of the agreement. But, this Canadian move is a domestic law and cannot be assumed to have been accepted by trading partners. Accordingly, when water has entered into commerce, it can be traded as a good and all provisions of the trade in goods as stated in the NAFTA apply. These provisions includes national treatment status, i.e., no difference between the investors of home and other nation. Thus, virtual water falls under NAFTA (Article 201-definition of goods of a party) and GATT (HS Code 22.01.9 - all natural water other than sea water provisions by virtue of its definition.

As argued by Holm (1993), NAFTA's environmental provision to protect the health of human, animal or plant life does not allow Canada to restrict or prohibit the export of water or water-intensive products. A closer look at the definition of sanitary or phytosanitary measure in chapter 7B, Article 724 reveals that, it is:

> …a measure that a Party adopts, maintains or applies to protect animal or plant life or health in its territory from risks arising from the introduction, establishment or spread of a pest or disease…the presence of an additive, contaminant, toxin or disease-causing organism in a food, beverage or feedstuff… a disease causing organism or pest carried by an animal or plant, or a product thereof, or … from the introduction, establishment or spread of a pest… (NAFTA Secretariat, 2004)

In addition, NAFTA Article 104 makes no mention of the Canada Federal Water Policy or the Canadian implementing legislation (The North American Free Trade Act), making it more difficult to protect Canada's water resources.

Although NAFTA does not address the issues of "production process" in its text, Article 10(2) of the NAAEC (Secretariat of the Commission for Environmental Cooperation, 1993) allows the Environmental Council to consider and develop recommendations on a large number of issues, including "the environmental implications of goods throughout their life cycles." This puts the concept of virtual water in a favourable position since it is defined as the amount of water required in the production process of an agricultural commodity. Can virtual water estimation form part of this evaluation process? It is necessary to determine the actual process of the life cycle analysis or environmental impact analysis (Colyer, 2002) done by the CEC for virtual water to be included. This determination is however, beyond the scope of this research.

The proposition to acknowledge environmental issues in a trade agreement (although not directly a part of the main text) is commendable in itself. Parties would be able to highlight their environmental concerns based on such lifecycle analysis and impose restrictions. However, according to the CEC procedures, it is insufficient for the panel of scientists in the CEC to conclude that there is an environmental hazard to natural resources: they have to agree and prove that investment and trade should be interrupted because of it (Kirton, 2002).

As Johnson and Beaulieu (1996: 252) have pointed out, “the heavy multilateral procedure and the unpredictable legal tests involved make it unlikely that the procedures” (to justify trade sanctions) will ever be used. In general, the capacity of national and sub-national governments to impose restrictions for their own environmental security is weakened or eliminated by their obligations under the NAFTA provisions.

5.4 Final comments on Virtual Water in NAFTA

According to Krugman (2006) free trade causes additional benefits that go beyond the formal cost benefit analysis. In the case of NAFTA, there have been a lot of claims that suggest that the U.S. has benefited in its agricultural sector due to this trade liberalization (for discussion see Colyer, 2002; Duncan, 2003; Kennedy & Rosson, 2002; Qasmi & Fausti, 2001; Vaughan, 2004).

A case study by Krugman (2006) highlights how southern California has benefited from NAFTA and its free trade in fruits and vegetables with Mexico. Southern California is an arid region and most of its water has to be transported from eastern California through dams, aqueducts and capital-intensive structures. Yet farmers get their water in heavily subsidized prices compared to urban consumers. Economists studying NAFTA have highlighted the fact that due to the increased imports of fruits and vegetables from Mexico, southern California’s water agriculture has contracted, freeing water that be utilized in other sectors. The potential hidden benefits are that urban consumers are facing less frequent water shortages, governments are spending less on water infrastructures and there is less ecological damages.

A similar case may be made for Canada-U.S. trade relations and the growing dependence on Canadian agricultural commodities, especially livestock and meat products. As has been highlighted in the research findings, a major portion of Canada’s livestock export (almost 100% of cattle and swine) categories end up across the border. By importing agricultural commodities, the U.S. is able to enjoy hidden social, economic and environmental benefits at Canada's cost.

The political discourse that virtual water offers is precisely what Allan (1997, 1998, 2000) had perceived for the MENA (Middle East North Africa) concerning water. For any country, it is not politically feasible to acknowledge either the actual problem of water deficiency or the actual solution of importation of virtual water. This recognition of the role of global "virtual water" is difficult because: (1) it is an unfamiliar concept and, (2) it would be politically unwelcome since the problem of water deficiency will then come into the spotlight, and politicians are weary of this acknowledgement (Allan, 2000).

5.5 Conclusion

This chapter summarized the findings with respect to the research questions and helped conceptualize the standpoint of virtual water in the NAFTA regime. By exploring the environmental provisions of NAFTA and drawing from discussion from section 2.4, it has been established that incorporation of VW estimations is plausible in generating dispute claims by affected parties. However, the sketchy and tedious decentralized process of dispute settlement and restrictions against barriers to investment under NAFTA leaves room for much needed discussion and investigation.

6 Recommendations

This research addressed the concept of virtual water in the water management arena and its role in estimating effects of free trade between Canada and the U.S. It also investigated the provisions of the NAFTA regarding water and environment. While this study contributes to a small body of literature on Canadian agricultural water use, much more is needed to fine-tune the estimation of virtual water flows and to understand the complex problems associated with trade. This chapter provides a list of recommendations that will serve to position virtual water in the scientific community and strengthen NAFTA’s capacity to ensure environmental protection and scope for further research.

6.1 Recommendations

Recommendations to address Virtual Water in Water Management Community:

1. *Establishment of definition and methodological framework*: The virtual water concept has varied interpretations in the scholarly literature. The definition of the term has evolved over the years and authors of various scientific communities have adapted the concept to fit their field of work. There is a need to establish a universal definition that is focused and narrow and upon which a methodological framework can be established. There is a need to investigate whether *service water* should (as included by Chapagain & Hoekstra, 2003) or should not (as in this research) form part of the virtual water calculation. This refinement is necessary to avoid large discrepancies in estimation of virtual water contents in agricultural products.
2. *Data collection and dissemination*: This study consisted of data and statistics obtained from heterogeneous sources. Inconsistent data and data shortages, especially for the provincial levels, posed a serious problem which may be the reason why such quantifications have not been attempted thus far. It also points to a general lack of quantitative information on the livestock sector. There is definitely room for future

improvements in the type of data collected and stored in the national and provincial governmental data depositories.

3. *Inclusion in water management literature:* Virtual water should have a place in the water management literature as a separate and distinguished entity and not compared to terms like life-cycle analysis, crop-water requirement and so on. Virtual water requires a well-established definition and logical methodology as recommended in point 1.

Recommendations to address water issues under NAFTA

Establishment of stricter guidelines: The NAFTA has strong enforcement clauses for trade, but weak and nonexistent ones for the environment. It creates an opportunity for integrating economies without concerns for integrating environmental regimes. It prohibits export limitations and hence limits national and sub-national government's capacities to protect the environment. The following recommendations are suggested to enhance NAFTA's environmental standings:

i. It should be revised to include provisions that specifically ban bulk water exports.
ii. It should recognize the role virtual water and its transfers in commodities. This can be highlighted as part of the environmental provisions. A 'water tax' system should be developed for water-intensive agricultural commodities.
iii. It should provide disincentives to investments and production that causes resource exploitation in excess of the carrying capacities. For instance, Alberta has already reached its ecological limits of how much water it can extract for agricultural purposes. However, increasing pressure from livestock production and trade is causing Alberta to stretch its water capacities. In cases like this, NAFTA provisions should discourage further growth and incentive in the sector.
iv. It should establish measures to include cost of resource exploitation and waste generation in its trading price. Price of goods increases when negative externalities are considered in the cost of production. VW accounting would make prices more reflective of the true cost of water-intensive goods and commodities.
v. NAFTA provisions should enable countries to refuse to export resources or goods that threaten to deplete or pose environmental hazard.

6.2 Suggestions for Future Research

There is a great deal of future research to be conducted in the virtual water field. For one, it is suggested that virtual water contents of different species of livestock grown in Canada be determined. This determination will allow refinement of the virtual water flow estimation since species differ in physiology and characteristics. Second, a virtual water flow calculation should be conducted for all water-intensive agricultural commodities. This expansion of the calculations will provide a broader picture to the scientific community on the state of agricultural water resource utilization in Canada. Third, a methodology should be created to estimate intra-provincial and inter-provincial trade of agricultural commodities. This detail will allow provinces to determine their local water footprint (Chapagain & Hoekstra, 2004; Hoekstra, 2003). Fourth, a trend analysis should be conducted to estimate the changes in virtual water requirements in the future due to changes in Canadian dietary needs. Finally, a comprehensive virtual water flow methodology should be established for Canada to determine its national water footprint based on trade with all nations.

6.3 Conclusion

This chapter provided a list of recommendations to address virtual water in the environmental management community. It also included suggestions to improve the provisions under NAFTA which promote the protection of water and the environment. The virtual water concept is in its latent stages of development and more research and fine-tuning of the methodological framework is necessary to make it a well-rounded and accepted terminology in the water management literature. Only then can a comprehensive evaluation be carried out to determine the real cost to water resources due to globalization.

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Appendices

Appendix 1: Definitions

Definitions have been taken from *Livestock feed Requirements Study* (Catalogue no. 23-501-XIE, Statistics Canada, 2003):

1. Beef Cattle all beef cows; beef replacement heifers both over and less than one year for herd replacement; slaughter steers, heifers and calves, breeding bulls both over and under one year of age intended for breeding.
   - Bulls: males over one year of age being retained for breeding in beef herds.
   - Beef cows: females, which have calved at least once and are used for breeding.
   - Beef heifers > 1 year for beef herd replacement: females one year and older which have never calved but are being retained for breeding.
   - Beef heifers < 1 year for beef herd replacement: females under one year of age that are being retained for breeding.
   - Bull calves: males less than one year of age being retained for breeding.
   - Calf slaughter: calves under one year of age slaughtered for meat.

2. Dairy Cattle all dairy cows; dairy heifers over and under one year of age for herd replacement; and bulls in dairy herds.
   - Dairy cows: females which have calved at least once and which are used to reproduce dairy cattle or mainly for milking purposes.
   - Dairy heifers over one year of age for herd replacement: females one year or older which have never calved and which are being retained for breeding and milking.
   - Dairy bulls: bulls one year of age or older being retained for breeding on dairy farms.
   - Replacement calves: calves less than one year old, which are being retained on dairy farms as future breeding stock.

3. Sheep and Lambs ewes, wethers and rams; market and breeding lambs.
   - Rams and ewes: sheep one year or older.
   - Replacement lambs: sheep less than one year of age being retained for breeding purposes.
   - Market lambs: lambs under one year of age regardless of sex slaughtered for meat.

4. Hogs all sows and bred gilts; boars; weaner pigs and market pigs.
   - Boars: male hogs six months of age or older retained for breeding.
   - Sows and bred gilts: female pigs that have farrowed or been bred to farrow.
   - Market hogs: finished hogs slaughtered for meat and retained for breeding.

Appendix 2: Livestock Conversion coefficients

Beef cattle		variable name	coefficient	Dairy cattle		variable name	coefficient
	cows	bfcows	1.000		cows	mlkcow	1.333
	calves	calfu1	0.227		calves	calfu1	0.303
	heifers	bfheif	0.714		heifers	mlkheif	1.000
	feeder heifers	fdheif	0.714		steers	steers	0.833
	steers	steers	0.769		bulls	bulls	1.333
	bulls	bulls	1.000				
Pig				**Poultry**			
	boars	boars	0.200		broilers	broiler	0.005
	sows	sows	0.200		pulets	pulets	0.003
	nursing pigs	nurpig	0.125		laying hens	layhen	0.008
	growing pigs	grwpig	0.033		turkeys	turkey	0.012
Other livestock and poultry							
	horses	horses	1.333		wild boars	otherpig	0.250
	goats	goats	0.143		rams	rams	0.143
	rabbits	rabbit	0.025		ewes & wethers	ewes	0.200
	mink	mink	0.013		lambs	lambs	0.063
	foxes	fox	0.025		other sheep	othersh	0.143
	bisons	bison	1.000		duck	duck	0.020
	deers	deer	0.125		ostriches	ostrich	0.143
	elks	elk	0.600		emus	emu	0.063
	llamas	lamas	0.143		other chicken	otherch	0.010
	other cattle	othercat	1.000				

Note: *Animal units are calculated by multiplying number of animals by the specific coefficient for each type of animal.*

Source: Beaulieu and Bédard, 2003

Appendix 3: Number of animals in each province by type (1991-2006)

Appendix 3: Number of Animals in each Province by type (1991-2006)

Category	Canada 1991	Canada 1996	Canada 2001	Canada 2006	Newfoundland 1991	Newfoundland 1996	Newfoundland 2001	Newfoundland 2006	Prince Edward Island 1991	Prince Edward Island 1996	Prince Edward Island 2001	Prince Edward Island 2006
	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals
Total cattle and calves	12,972,038	14,893,034	15,551,449	16,250,000	8,446	8,252	9,483	9,100	94,573	94,611	84,791	84,500
Total beef cows	3,828,630	4,680,585	4,802,400	5,215,500	661	732	649	400	12,977	16,472	13,251	13,300
Total dairy cows	1,315,178	1,227,732	1,060,965	1,035,500	4,825	4,443	4,708	4,900	18,318	16,353	14,623	15,000
Total sheep and lambs	935,891	864,850	1,262,448	1,156,200	8,918	6,402	7,888	7,800	3,394	2,996	3,589	4,400
Total pigs	10,216,083	11,040,462	13,958,772	14,521,000	15,625	4,452	2,689	2,400	106,728	117,560	126,065	115,600
Total hens and chickens	94,872,875	102,255,149	126,159,529	125,314,793	1,304,604	1,477,816	1,720,697	X	429,724	352,488	365,182	X

Category	Nova Scotia 1991	Nova Scotia 1996	Nova Scotia 2001	Nova Scotia 2006	New Brunswick 1991	New Brunswick 1996	New Brunswick 2001	New Brunswick 2006	Quebec 1991	Quebec 1996	Quebec 2001	Quebec 2006
	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals
Total cattle and calves	128,619	128,971	108,401	107,000	105,137	100,297	91,176	90,500	1,445,906	1,439,743	1,362,788	1,455,000
Total beef cows	27,629	32,068	26,500	26,800	22,267	22,881	20,397	21,000	187,498	231,891	207,852	225,000
Total dairy cows	28,913	26,623	23,918	22,900	23,330	21,265	18,978	19,000	514,542	471,855	407,206	400,000
Total sheep and lambs	31,670	23,506	24,896	25,700	10,217	7,266	9,601	9,300	121,253	151,557	254,053	280,000
Total pigs	133,640	130,707	124,935	99,000	76,093	74,471	137,006	106,000	2,909,251	3,443,832	4,267,365	4,140,000
Total hens and chickens	3,616,704	3,558,559	4,084,846	X	2,413,042	2,663,684	3,487,452	X	23,035,296	25,440,825	29,212,229	X

Category	Ontario 1991	Ontario 1996	Ontario 2001	Ontario 2006	Manitoba 1991	Manitoba 1996	Manitoba 2001	Manitoba 2006	Saskatchewan 1991	Saskatchewan 1996	Saskatchewan 2001	Saskatchewan 2006
	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals
Total cattle and calves	2,285,954	2,285,996	2,140,731	2,203,900	1,108,780	1,355,162	1,424,427	1,720,000	2,285,844	2,723,642	2,899,502	3,450,000
Total beef cows	389,659	441,211	376,020	383,000	411,131	510,197	563,300	685,000	898,339	1,135,027	1,215,216	1,508,000
Total dairy cows	442,996	404,797	363,544	344,700	56,106	59,404	42,407	39,000	45,324	38,154	30,136	27,500
Total sheep and lambs	251,620	231,087	337,625	302,000	36,860	38,152	84,798	65,000	92,181	72,464	149,389	142,000
Total pigs	2,924,936	2,831,082	3,457,346	3,600,000	1,287,196	1,777,352	2,540,220	2,980,000	808,968	757,027	1,109,797	1,340,000
Total hens and chickens	34,059,285	35,596,946	43,624,696	X	6,409,151	6,403,908	7,985,741	X	3,618,109	3,516,027	4,683,093	X

Category	Alberta 1991	Alberta 1996	Alberta 2001	Alberta 2006	British Columbia 1991	British Columbia 1996	British Columbia 2001	British Columbia 2006
	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals	# of animals
Total cattle and calves	4,756,365	5,942,257	6,615,201	6,300,000	752,414	814,103	814,949	830,000
Total beef cows	1,635,727	2,016,889	2,099,288	2,065,000	242,742	273,217	279,927	288,000
Total dairy cows	105,905	102,830	84,044	88,000	74,919	82,008	71,401	74,500
Total sheep and lambs	305,642	259,817	307,302	245,000	74,136	71,603	83,307	75,000
Total pigs	1,729,870	1,729,810	2,027,533	1,970,000	223,776	174,169	165,816	168,000
Total hens and chickens	8,702,434	9,485,635	12,175,246	X	11,284,526	13,759,261	18,820,347	X

Notes:

Census of Agriculture 2006 is as of July 01, 2006
Census of Agriculture 2006 values are rounded to '000
Poultry Values for 2006 are not availble for provinces

Appendix 4: Virtual Water Content Calculation

Kind of animal: Beef Cattle

Average Live weight of an adult bovine at slaughter **0.61** **ton/animal**

Water for Drinking

	Calve	Adult cow
Age (months)	5	36
Range of daily consumption (l/day/animal)	11.36	37.85
Average daily consumption (l/day/animal)	24.61	
Total Drinking Water Required (l/animal)	**26942.67**	
Conversion (m3/animal)	**26.94**	

Water for feed

	Feed Quantity (ton/yr)			SWD	Crop Water	
Feed crop	**Beef cattle**	**Beef rep heifer < 1 yr**	**Average feed volume**	**m3/ton**	**m3/yr**	
Wheat	0.006	0.004	0.005	1441	7.21	
Oats	0.041	0.089	0.065	2328	151.32	
Barley	0.09	0.042	0.066	1098	72.47	
Other small grain	0.002	0.003	0.0025	897	2.24	
Grain corn	0.002	0.014	0.008	381	3.05	
Dry peas	0.002	0.004	0.003	1377	4.13	
Soyabean meal	0.002	0.002	0.002	1227	2.45	
Canola meal	0.006	0.008	0.007	1098	7.69	
Mill screen	0.014	0.011	0.0125	1441	18.01	
Total grain	0.165	0.177	0.171			
Non grain portion	0.003	0.003	0.003	381	1.14	**Grain**
Complete grain based ration	0.168	0.18	0.174			**269.71**
Pasture	2.043	0.524	1.2835	445	571.16	
Dry Hay	1.523	0.528	1.0255	494	506.60	
Silage	0.47	0.129	0.2995	494	147.95	
Other roughages	0.479	0.1	0.2895	445	128.83	**Forage**
Total roughages	4.515	1.281	2.898			**1354.535**

Total water consumption in the form of feed per year **1624.25** **m3/yr**
Total volume of water from feed = Age * water volume **4872.74** **m3/animal**

Mixing Water for feed preparation

	Average		
Total Feed Volume (ton/yr)	3.069	(only roughages)	
Mixing water required for feed preparation	1.5345	(m3/yr)	
(50% of total feed consumed)			
Total Quantity (for the full lifespan)	**4.60**	(m3/yr)	
Virtual Water content of feed	(Total Volume of Water from feed	**4877.34**	m3/animal
	+ Mixing Water for feed preparation)		

VWC Calcultion

Beef Cattle		
	Water per animal	
Water from drinking	26.94	m3/animal
Water from feed	4877.34	m3/animal
Total (lifetime)	4904.28	m3/animal
Water Content/ Body weight = 54.9 - 57.8% ~ 56%		
Total VWC (beef cattle)	**2746.40**	**m3/animal**

Cattle Primary Product - Beef/ Veal		
Total Carcass weight of live weight = 44 - 55% ~ 50%		
Water Content in Carcass	1373.20	m3
Total VWC (beef)	**2251.15**	**m3/ton**

Source:	
Weight and Drinking Water Requirements	Ministry of Agriculture and Lands B.C. 2006
Feed data	Livestock Feed Requirements Study, Statistics Canada (Catalogue no. 23-501-XIE)
Specific Water Demand (SWD)	Chapagain and Hoekstra, 2003
Mixing Water	Chapagain and Hoekstra, 2003
Water Content/body weight	Gad and Preston; Journal of Animal Science: 68(11):3649, 1990
Carcass Weight	OMAFRA: http://www.omafra.gov.on.ca/english/livestock/beef/facts/05-075.htm

Kind of animal: Dairy Cows

Average Live weight of an adult bovine at slaughter **0.36** **ton/animal**

Water for Drinking

	Calve	Heifers	Milking Cow
Age (years)	0-1	1-3	3-10
Range of daily consumption (l/day/animal)	13.25	45.42	136.27
Average daily consumption (l/day/animal)	64.98		
Total Drinking Water Required (l/animal)	**237187.59**		
Conversion (m3/animal)	**237.19**		

Water for feed

Feed crop	Feed Quantity (ton/yr) Calves< 1 yrs	Heifers	Milking Cow	Average feed volume	SWD m3/ton	Crop Water (m3/yr)	
Wheat	0.023	0.008	0.091	0.04	1441	58.60	
Oats	0.064	0.011	0.02	0.03	2328	73.72	
Barley	0.157	0.111	0.748	0.34	1098	371.86	
Other small grain	0.027	0.018	0.052	0.03	897	29.00	
Grain corn	0.263	0.186	1.443	0.63	381	240.28	
Dry peas	0	0	0.003	0.00	1377	1.38	
Soyabean meal	0.077	0.043	0.266	0.13	1227	157.87	
Canola meal	0.021	0.005	0.095	0.04	1098	44.29	
Mill screen	0.035	0.006	0.218	0.09	1441	124.41	
Total grain	0.666	0.387	2.938	1.33			
Non grain portion	0.025	0.011	0.162	0.07	381	25.15	**Grain**
Complete grain based ration	0.691	0.398	3.099	1.40			**1126.553**
Pasture	0.059	0.542	0.326	0.31	445	137.51	
Dry Hay	1.063	1.459	1.027	1.18	494	584.40	
Silage	0.425	1.335	2.976	1.58	494	779.86	
Other roughages	0.054	0.029	0	0.03	445	12.31	**Forage**
Total roughages	1.602	3.365	4.328	3.10			**1514.08**

Total water consumption in the form of feed per year **2640.63**

Total volume of water from feed = Age * water volume **26406.33**

Mixing Water for feed preparation

	Average		
Total Feed Volume (ton/yr)	4.43	(only roughages)	
Mixing water required for feed preparation	2.214333333	(m3/yr)	
(50% of total feed consumed)			
Total Quantity (for the full lifespan)	**22.14**	(m3/yr)	
Virtual Water content of feed	(Total Volume of Water from feed + Mixing Water for feed preparation)	**26428.47**	m3/animal

VWC Calcultion

Dairy Cattle		
	Water per animal	
Water from drinking	237.19	m3/animal
Water from feed	26428.47	m3/animal
Total (lifetime)	26665.66	m3/animal
Water Content/ Body weight = 62.4 - 69% ~ 66%		
Total VWC (Dairy Cow)	**17599.34**	**m3/animal**

Dairy Primary Product - Milk
Percentage of water in milk = 87.6%

Source:	
Weight and Drinking Water Requirements	Ministry of Agriculture and Lands B.C. 2006
Feed data	Livestock Feed Requirements Study, Statistics Canada (Catalogue no. 23-501-XIE)
Specific Water Demand (SWD)	Chapagain and Hoekstra, 2003
Mixing Water	Chapagain and Hoekstra, 2003
Water Content/body weight & %of water in milk	Board on Agriculture and Natural Resources, Nutrients Requirements in Dairy Cattle, 2003

Kind of animal: Swine

Average Live weight of an adult swine at slaughter **0.12** **ton/animal**

Water for Drinking

	Weaner/Piglet	Adult
Age (months)	0.5	12
Range of daily consumption (l/day/animal)	2.27	90.84
Average daily consumption (l/day/animal)	46.56	
Total Drinking Water Required (l/animal)	**16992.58**	
Conversion (m3/animal)	**16.99**	

Water for feed

	Feed Quantity (ton/yr)			SWD	Crop Water	
Feed crop	**Weaner**	**Feeder - Adult**	**Average feed volume**	**m3/ton**	**m3/yr**	
Wheat	0.001	0.028	0.0145	1441	20.89	
Oats	0	0	0	2328	0.00	
Barley	0.003	0.063	0.033	1098	36.23	
Other small grain	0	0	0	897	0.00	
Grain corn	0.013	0.12	0.0665	381	25.34	
Dry peas	0.001	0.007	0.004	1377	5.51	
Soyabean meal	0.005	0.032	0.0185	1227	22.70	
Canola meal	0	0.012	0.006	1098	6.59	
Mill screen	0	0.003	0.0015	1441	2.16	
Total grain	0.023	0.266	0.1445			
Non grain portion	0.004	0.011	0.0075	381	2.86	**Grain**
Complete grain based ration	0.027	0.277	0.152			**122.2795**

Total water consumption in the form of feed per year **122.28** **m3/yr**
Total volume of water from feed = Age * water volume **122.28** **m3/animal**

Mixing Water for feed preparation

	Average		
Total Feed Volume (ton/yr)	0.152	(only roughages)	
Mixing water required for feed preparation (m3/yr)	0.076		
(50% of total feed consumed)			
Total Quantity (for the full lifespan)	**0.08**		
Virtual Water content of feed	(Total Volume of Water from feed	**122.36**	m3/animal
	+ Mixing Water for feed preparation)		

VWC Calcultion

Swine		
	Water per animal	
Water from drinking	16.99	m3/animal
Water from feed	122.36	m3/animal
Total	139.35	m3/animal
Water Content/ Body weight = 51 - 82% ~ 66.5%		
Total VWC (swine)	**92.67**	**m3/animal**

Swine Primary Product - Pork		
Total Carcass weight of live weight = 45.81% ~ 46%		
Water Content in Carcass	42.63	m3
Total VWC (pork)	**355.22**	**m3/ton**

Source:	
Live Weight	Source: http://www.manitobapork.com/admin/docs/Prusa_Swine_Econ_Report-20050707161133.pdf
Weight and Drinking Water Requirements	Ministry of Agriculture and Lands B.C. 2006
Feed data	Livestock Feed Requirements Study, Statistics Canada (Catalogue no. 23-501-XIE)
Specific Water Demand (SWD)	Chapagain and Hoekstra, 2003
Mixing Water	Chapagain and Hoekstra, 2003
Water Content/body weight	ThePigSite.com
Carcass Weight	R. H. Gnaedinger; Journal of Animal Science: 22 (2):495, 1964

Kind of animal: Sheep and Lamb

Average Live weight of an adult sheep at slaughter **0.05** **ton/animal**

Water for Drinking

	Feeder Lamb/ Kid	Adult
Age (months)	0.2	24
Range of daily consumption (l/day/animal)	7.57	9.46
Average daily consumption (l/day/animal)	8.52	
Total Drinking Water Required (l/animal)	**6215.95**	
Conversion (m3/animal)	**6.22**	

Water for feed

	Feed Quantity (ton/yr)	SWD	Crop Water	
Feed crop	**Average feed volume**	**m3/ton**	**m3/yr**	
Wheat	0.001	1441	1.44	
Oats	0.006	2328	13.97	
Barley	0.026	1098	28.55	
Other small grain	0.001	897	0.90	
Grain corn	0.005	381	1.91	
Dry peas	0.001	1377	1.38	
Soyabean meal	0.002	1227	2.45	
Canola meal	0.001	1098	1.10	
Mill screen	0.001	1441	1.44	
Total grain	0.043			
Non grain portion	0.001	381	0.38	**Grain**
Complete grain based ration	0.043			**53.51**
Pasture	0.171	445	76.10	
Dry Hay	0.205	494	101.27	
Silage	0.034	494	16.80	
Other roughages	0.003	445	1.34	**Forage**
Total roughages	0.413			**195.496**

Total water consumption in the form of feed per year **249.01** **m3/yr**
Total volume of water from feed = Age * water volume **498.01** **m3/animal**

Mixing Water for feed preparation

	Average		
Total Feed Volume (ton/yr)	0.456	(only roughages)	
Mixing water required for feed preparation	0.228	(m3/yr)	
(50% of total feed consumed)			
Total Quantity (for the full lifespan)	**0.46**	(m3/yr)	
Virtual Water content of feed	(Total Volume of Water from feed	**498.47**	m3/animal
	+ Mixing Water for feed preparation)		

VWC Calcultion

Sheep and Lamb		
	Water per animal	
Water from drinking	6.22	m3/animal
Water from feed	498.47	m3/animal
Total	504.68	m3/animal
Water Content/ Body weight = 30%		
VWC (Sheep and Lamb)	**151.41**	**m3/animal**

Cattle Primary Product - Mutton		
Total Carcass weight of live weight = 43.2 - 48.6% ~ 46%		
Water Content in Carcass	69.65	m3
Total VWC (mutton)	**1392.93**	**m3/ton**

Source:

Weight and Drinking Water Requirements	Ministry of Agriculture and Lands B.C. 2006
Feed data	Livestock Feed Requirements Study, Statistics Canada (Catalogue no. 23-501-XIE)
Specific Water Demand (SWD)	Chapagain and Hoekstra, 2003
Mixing Water	Chapagain and Hoekstra, 2003
Water Content/body weight	E.L. Hix et al.; Journal of Animal Science: 12(3):459, 1953
Carcass Weight	estimated from: S.R. Silva et al.: Journal of Animal Science: 84(12):3433, 2006 and, S.R. Silva et al: Meat Science 76 (2007) 708–714

Kind of animal: Broiler Chicken

Average Live weight of an adult chicken at slaughter	**2.2**	**kg/animal**
	0.0022	**ton/animal**

Water for Drinking

	Chick	Adult
Age (weeks)		10
Range of daily consumption (l/day/animal)	0.02	0.16
Average daily consumption (l/day/animal)	0.09	
Total Drinking Water Required (l/animal)	**6.30**	
Conversion (m3/animal)	**0.01**	

Water for feed

	Feed Quantity (ton/yr)	SWD	Crop Water	`
Feed crop	**Chicken**	**m3/ton**	**m3/yr**	
Wheat	0.0007	1441	1.01	
Oats	0	2328	0.00	
Barley	0.0003	1098	0.33	
Other small grain	0	897	0.00	
Grain corn	0.0014	381	0.53	
Dry peas	0	1377	0.00	
Soyabean meal	0.0005	1227	0.61	
Canola meal	0.0001	1098	0.11	
Mill screen	0.0001	1441	0.14	
Total grain	0.0031			
Non grain portion	0.0008	381	0.30	**Grain**
Complete grain based ration	0.0039			**3.04**
	Total water consumption in the form of feed per year		**3.04**	**m3/yr**
	Total volume of water from feed = Age * water volume		**5.84**	**m3/animal**

Mixing Water for feed preparation

	Average		
Total Feed Volume (ton/yr)	0.0039	(only roughages)	
Mixing water required for feed preparation (m3/yr)	0.00195		
(50% of total feed consumed)			
Total Quantity (for the full lifespan)	**0.0004**		
Virtual Water content of feed	(Total Volume of Water from feed	**5.84**	m3/animal
	+ Mixing Water for feed preparation)		

VWC Calcultion

Chicken		
	Water per animal	
Water from drinking	0.01	m3/animal
Water from feed	5.84	m3/animal
Total	5.84	m3/animal
Water Content/ Body weight = 64%		
Total VWC (Chicken)	**3.74**	**m3/animal**

Chicken Primary Product - meat		
Total Carcass weight of live weight = 1.6 kg = 73%		
Water Content in Carcass	2.73	m3
Total VWC (Chicken Meat)	**1241.03**	**m3/ton**

Source:	
Live Weight	Chapagain and Hoekstra, 2003
Weight and Drinking Water Requirements	Ministry of Agriculture and Lands B.C. 2006
Feed data	Livestock Feed Requirements Study, Statistics Canada (Catalogue no. 23-501-XIE)
Specific Water Demand (SWD)	Chapagain and Hoekstra, 2003
Mixing Water	Chapagain and Hoekstra, 2003
Water Content/body weight	Latshaw and Bishop, Poultry Science, 80 (7): 868, 2001
Carcass Weight	Chapagain and Hoekstra, 2003

Appendix 5: Virtual Water flow Calculation

VWC of Beef and Dairy Cattle trade with U.S.

Year	Total Cattle Export *head*	Total Cattle Imports *head*	Total Exports (to US) *Beef Cattle*	Total Exports (to US) *Dairy Cattle*	*Export to US as % of total export trade*	Total Imports (from US) *Beef Cattle*	Total Imports (from US) *Dairy Cattle*	*Import to US as % of total import trade*
1993	1,235,400	60,600	1,172,400	29,900	*97.3*	49,200	3,800	*87.5*
1994	1,017,100	117,200	991,870	18,400	*99.3*	87,900	5,500	*79.7*
1995	1,135,600	86,500	1,105,200	27,600	*99.8*	62,900	3,900	*77.2*
1996	1,513,000	60,100	1,480,900	28,200	*99.7*	51,600	3,200	*91.2*
1997	1,380,800	49,900	1,357,300	19,500	*99.7*	47,800	2,000	*99.8*
1998	1,315,400	111,100	1,257,700	55,700	*99.8*	107,000	270	*96.6*
1999	986,100	222,400	914,290	71,000	*99.9*	220,000	1,200	*99.5*
2000	964,800	352,900	899,350	64,900	*99.9*	344,000	4,300	*98.7*
2001	1,307,200	301,600	1,230,700	75,500	*99.9*	291,000	3,600	*97.7*
2002	1,688,100	138,400	1,618,200	68,200	*99.9*	130,000	3,700	*96.6*
2003	505,600	62,900	478,300	27,200	*100.0*	58,400	2,100	*96.2*
2004	0	18,700	0	0	-	15,700	3,000	*100.0*
2005	558,900	21,100	557,730	330	*99.8*	10,900	10,200	*100.0*
2006	1,031,900	38,100	1,030,900	73	*99.9*	29,900	8,000	*99.5*

	Beef Cattle				Dairy Cattle			
Year	VWC (Exports to US) *Mm3*	VWC (Imports from US) *Mm3*	Ratio *Ex/Im*	Difference *Mm3*	VWC (Exports to US) *Mm3*	VWC (Imports from US) *Mm3*	Ratio *VWC Exp / VWC Imp*	Difference *Mm3*
1993	3,219.9	135.1	23.83	3,084.8	526.2	66.9	7.87	459.3
1994	2,724.1	241.4	11.28	2,482.7	323.8	96.8	3.35	227.0
1995	3,035.3	172.7	17.57	2,862.6	485.7	68.6	7.08	417.1
1996	4,067.1	141.7	28.70	3,925.4	496.3	56.3	8.81	440.0
1997	3,727.7	131.3	28.40	3,596.4	343.2	35.2	9.75	308.0
1998	3,454.1	293.9	11.75	3,160.3	980.3	4.8	206.30	975.5
1999	2,511.0	604.2	4.16	1,906.8	1,249.6	21.1	59.17	1,228.4
2000	2,470.0	944.8	2.61	1,525.2	1,142.2	75.7	15.09	1,066.5
2001	3,380.0	799.2	4.23	2,580.8	1,328.7	63.4	20.97	1,265.4
2002	4,444.2	357.0	12.45	4,087.2	1,200.3	65.1	18.43	1,135.2
2003	1,313.6	160.4	8.19	1,153.2	478.7	37.0	12.95	441.7
2004	0.0	43.1	0.00	-43.1	0.0	52.8	0.00	-52.8
2005	1,531.7	29.9	51.17	1,501.8	5.8	179.5	0.03	-173.7
2006	2,831.3	82.1	34.48	2,749.1	1.3	140.8	0.01	-139.5
Average	**2,765.0**	**295.5**	**17.1**	**2,469.5**	**611.6**	**68.9**	**26.4**	**542.7**

Key:

VWC of Beef Cattle (m3/animal) **2746.40** 3012.24

VWC of Dairy Cattle (m3/animal) **17599.34**

Source Total Cattle Export/Import: Cattle Statistics, 2007, Statistics Canada, Catalogue no. 23-012-XIE
Total Cattle Export/Import to/from U.S. (1993-2006): Red Meat Market Information, AAFC, Import/Export of cattle, sheep and hog from /to U.S. (1993-2006)
Total Beef/Veal Import/Export: Alberta Trade in beef and Live Cattle: A five year perspective (1999-2003, 2000-2004, 2002-2006)
(Alberta Agriculture and Food website)

VWC of Beef and Veal trade with U.S.

Year	Total Export	Total Imports	Total Exports (to US)	*Export to US as %*	Total Imports (from US)	*Import from US as %*	VWC (Exports to US)	VWC (Imports from US)	Ratio	Difference
	tonnes	*tonnes*	*tonnes*	*of total export trade*	*tonnes*	*of total import trade*	*Mm3*	*Mm3*	*VWC Exp / VWC Imp*	*Mm3*
1989	104,000	65,040	96,500	*92.8*	31,400	*48.3*	217.2	70.7	3.1	146.5
1990	94,300	158,500	85,000	*90.1*	64,900	*40.9*	191.3	146.1	1.3	45.2
1991	94,600	179,500	86,900	*91.9*	85,900	*47.9*	195.6	193.4	1.0	2.3
1992	144,300	177,300	134,200	*93.0*	78,700	*44.4*	302.1	177.2	1.7	124.9
1993	177,300	213,400	164,700	*92.9*	75,600	*35.4*	370.8	170.2	2.2	200.6
1994	212,000	227,200	189,900	*89.6*	88,300	*38.9*	427.5	198.8	2.2	228.7
1995	214,400	200,100	188,600	*88.0*	96,000	*48.0*	424.6	216.1	2.0	208.5
1996	275,100	186,000	248,400	*90.3*	89,700	*48.2*	559.2	201.9	2.8	357.3
1997	328,500	198,900	289,800	*88.2*	84,200	*42.3*	652.4	189.5	3.4	462.8
1998	366,700	189,100	327,200	*89.2*	76,000	*40.2*	736.6	171.1	4.3	565.5
1999	419,800	206,900	368,200	*87.7*	72,000	*34.8*	828.9	162.1	5.1	666.8
2000	445,900	214,100	354,700	*79.5*	72,900	*34.0*	798.5	164.1	4.9	634.4
2001	489,700	247,200	377,700	*77.1*	65,800	*26.6*	850.3	148.1	5.7	702.1
2002	521,500	251,900	409,600	*78.5*	66,600	*26.4*	922.1	149.9	6.2	772.1
2003	324,800	222,700	267,700	*82.4*	63,000	*28.3*	602.6	141.8	4.2	460.8
2004	454,900	90,230	361,100	*79.4*	11,800	*13.1*	812.9	26.6	30.6	786.3
2005	458,500	110,600	380,900	*83.1*	25,200	*22.8*	857.5	56.7	15.1	800.7
2006	365,700	111,300	302,900	*82.8*	67,800	*60.9*	681.9	152.6	4.5	529.2
Average*							**680.4**	**153.5**	**6.7**	**526.8**

VWC of Beef/Veal (m3/ton) **2251.15**

VWC of Milk trade with U.S.

Year	Total Exports (to US)	Total Imports (from US)	VWC (Exports to US)	VWC (Imports from US)	Ratio	Difference
	litres	*litres*	*Tm3*	*Tm3*	*VWC Exp / VWC Imp*	*Tm3*
1989	5,632,000	579,000	4,933.6	507.2	9.7	4,426.4
1990	6,061,000	62,900	5,309.4	55.1	96.4	5,254.3
1991	7,571,000	26,300	6,632.2	23.0	287.9	6,609.2
1992	2,164,000	94,400	1,895.7	82.7	22.9	1,813.0
1993	43,200	57,500	37.8	50.4	0.8	-12.5
1994	0	55,100	0.0	48.3	0.0	-48.3
1995	102,200	118,000	89.5	103.4	0.9	-13.8
1996	3,658,000	125,000	3,204.4	109.5	29.3	3,094.9
1997	5,762,000	68,100	5,047.5	59.7	84.6	4,987.9
1998	6,420,000	53,400	5,623.9	46.8	120.2	5,577.1
1999	10,630,000	204,000	9,311.9	178.7	52.1	9,133.2
2000	4,781,000	318,000	4,188.2	278.6	15.0	3,909.6
2001	6,278,000	0	5,499.5	0.0	-	5,499.5
2002	7,953,000	45,700	6,966.8	40.0	174.0	6,926.8
2003	5,386,000	4,985,000	4,718.1	4,366.9	1.1	351.3
2004	3,816,000	11,030,000	3,342.8	9,662.3	0.3	-6,319.5
2005	5,357,000	12,260,000	4,692.7	10,739.8	0.4	-6,047.0
2006	2,445,000	7,686,000	2,141.8	6,732.9	0.3	-4,591.1
Average*	**4,473,671**	**2,643,271**	**3,919**	**2,316**	**37**	**1,603**

Water Content in Milk **87.60%**

Milk includes <1% fat, 1-6% fat and >6% fat

***Average values are for values from 1993-2006**

Source

Total Beef/Veal Import/Export: Alberta Trade in beef and Live Cattle: A five year perspective (1999-2003, 2000-2004, 2002-2006) (Alberta Agriculture and Food website)

Beef and Veal Export (total & US) and Total Imports: Red Meat Section, AAFC, September 2006

Beef/Veal Import from U.S.: U.S. trade internet system: Foreign Agriculture Service, USDA

Dairy Cattle and Milk Export/Import: U.S. trade internet system: Foreign Agriculture Service, USDA

VWC of Swine trade with U.S.

Year	Total Export head	Total Imports head	Total Exports (to US) head	*Export to US as % of total export trade*	Total Imports (from US) head	*Import from US as % of total import trade*	VWC (Exports to US) Mm3	VWC (Imports from US) Mm3	Ratio VWC Exp / VWC Imp	Difference Mm3
1989	1,007,000	700	1,006,000	*99.9*	290	*41.4*	93.2	0.03	3,469.0	93.20
1990	891,700	600	887,700	*99.6*	580	*96.7*	82.3	0.05	1,530.5	82.21
1991	1,066,000	1,200	1,053,000	*98.8*	1,000	*83.3*	97.6	0.09	1,053.0	97.49
1992	671,800	1,200	669,800	*99.7*	550	*45.8*	62.1	0.05	1,217.8	62.02
1993	839,000	1,400	837,800	*99.9*	670	*47.9*	77.6	0.06	1,250.4	77.57
1994	915,400	4,500	914,800	*99.9*	2,500	*55.6*	84.8	0.23	365.9	84.54
1995	1,748,000	3,100	1,747,000	*99.9*	2,000	*64.5*	161.9	0.19	873.5	161.70
1996	2,779,000	2,200	2,780,000	*100.0*	1,300	*59.1*	257.6	0.12	2,138.5	257.49
1997	3,181,000	3,300	3,178,000	*99.9*	2,800	*84.8*	294.5	0.26	1,135.0	294.23
1998	4,123,000	9,400	4,122,000	*100.0*	6,500	*69.1*	382.0	0.60	634.2	381.37
1999	4,137,000	8,100	4,137,000	*100.0*	5,100	*63.0*	383.4	0.47	811.2	382.89
2000	4,360,000	7,900	4,357,000	*99.9*	4,500	*57.0*	403.7	0.42	968.2	403.33
2001	5,344,000	4,400	5,161,000	*96.6*	4,300	*97.7*	478.3	0.40	1,200.2	477.85
2002	5,740,000	13,800	5,738,000	*100.0*	12,000	*87.0*	531.7	1.11	478.2	530.61
2003	7,442,000	4,300	7,438,000	*99.9*	3,000	*69.8*	689.3	0.28	2,479.3	688.98
2004	8,511,000	3,300	8,509,000	*100.0*	3,000	*90.9*	788.5	0.28	2,836.3	788.22
2005	8,215,000	800	8,186,000	*99.6*	502	*62.8*	758.6	0.05	16,306.8	758.52
2006	8,777,000	600	8,763,000	*99.8*	561	*93.5*	812.0	0.05	15,620.3	811.98
Average*							**436.0**	**0.3**	**3364.1**	**435.7**

VWC of Swine (m3/animal) **92.67**

VWC of Pork with U.S.

Year	Total Export tonnes	Total Imports tonnes	Total Exports (to US) tonnes	*Export to US as % of total export trade*	Total Imports (from US) tonnes	*Import from US as % of total import trade*	VWC (Exports to US) Mm3	VWC (Imports from US) Mm3	Ratio VWC Exp / VWC Imp	Difference Mm3
1990	266,200	26,800	199,500	*82.1*	3,600	*13.4*	70.9	1.3	55.4	69.6
1991	243,000	33,300	188,000	*68.3*	4,800	*14.4*	66.8	1.7	39.2	65.1
1992	275,200	26,700	181,300	*64.3*	5,400	*20.2*	64.4	1.9	33.6	62.5
1993	281,900	33,700	188,100	*64.8*	8,000	*23.7*	66.8	2.8	23.5	64.0
1994	290,400	42,300	191,700	*54.7*	12,900	*30.5*	68.1	4.6	14.9	63.5
1995	350,600	42,800	204,800	*58.4*	13,500	*31.5*	72.7	4.8	15.2	68.0
1996	373,400	48,000	199,600	*53.5*	23,800	*49.6*	70.9	8.5	8.4	62.4
1997	423,200	56,600	205,500	*48.6*	34,300	*60.6*	73.0	12.2	6.0	60.8
1998	433,000	72,400	232,600	*53.7*	32,300	*44.6*	82.6	11.5	7.2	71.2
1999	519,600	74,100	287,600	*55.4*	29,700	*40.1*	102.2	10.6	9.7	91.6
2000	636,600	75,300	348,300	*54.7*	33,600	*44.6*	123.7	11.9	10.4	111.8
2001	718,700	92,500	366,100	*50.9*	46,700	*50.5*	130.0	16.6	7.8	113.5
2002	827,400	95,800	411,100	*49.7*	48,200	*50.3*	146.0	17.1	8.5	128.9
2003	924,300	108,800	450,900	*48.8*	47,500	*43.7*	160.2	16.9	9.5	143.3
2004	931,200	115,700	409,400	*44.0*	60,200	*52.0*	145.4	21.4	6.8	124.0
2005	1,029,000	133,300	388,500	*37.8*	80,200	*60.2*	138.0	28.5	4.8	109.5
Average*							**106.1**	**12.9**	**10.2**	**93.3**

VWC of Pork (m3/ton) **355.22**
***Average values are for values from 1993-2006**

Source
Total Hog/Pork Export/Import: Hog Statistics, 2007, Statistics Canada, Catalogue no. 23-010-XIE
Hog Export/Import to/from US: Red Meat Market Information, AAFC, Import/Export of cattle, sheep and hog from /to U.S. (1993-2006)
Alberta Trade in pork and live hog: A five year perspective (1999-2003, 2002-2006), (Alberta Agriculture and Food website)
Pork Export (total & US) and Import (total): Red Meat Section, AAFC, September 2006
Pork Import from U.S.: U.S. trade internet system: Foreign Agriculture Service, USDA

VWC of Sheep and Lamb trade with U.S.

Year	Total Export *head*	Total Imports *head*	Total Exports (to US) *head*	*Export to US as %* *of total export trade*	Total Imports (from US) *head*	*Import from US as %* *of total import trade*	VWC (Exports to US) *Mm3*	VWC (Imports from US) *Mm3*	Ratio *VWC Exp / VWC Imp*	Difference *Mm3*
1989	26,200	34,300	26,200	*100.0*	15,600	*45.5*	3.97	2.36	1.68	1.60
1990	25,700	35,700	25,200	*98.1*	35,700	*100.0*	3.82	5.41	0.71	-1.59
1991	22,600	28,100	22,500	*99.6*	28,100	*100.0*	3.41	4.25	0.80	-0.85
1992	27,600	13,900	27,300	*98.9*	13,400	*96.4*	4.13	2.03	2.04	2.10
1993	27,700	12,500	27,600	*99.6*	12,200	*97.6*	4.18	1.85	2.26	2.33
1994	28,500	19,600	28,400	*99.6*	19,200	*98.0*	4.30	2.91	1.48	1.39
1995	39,100	25,200	39,000	*99.7*	24,900	*98.8*	5.90	3.77	1.57	2.13
1996	44,500	27,200	44,500	*100.0*	27,200	*100.0*	6.74	4.12	1.64	2.62
1997	46,200	10,400	46,200	*100.0*	10,100	*97.1*	6.99	1.53	4.57	5.47
1998	46,100	14,600	46,100	*100.0*	14,100	*96.6*	6.98	2.13	3.27	4.84
1999	52,000	9,270	52,000	*100.0*	9,020	*97.3*	7.87	1.37	5.76	6.51
2000	51,700	2,800	51,500	*99.6*	2,730	*97.5*	7.80	0.41	18.86	7.38
2001	85,500	1,180	85,000	*99.4*	930	*78.8*	12.87	0.14	91.40	12.73
2002	139,000	1,100	139,000	*100.0*	904	*82.2*	21.05	0.14	153.76	20.91
2003	68,800	400	67,800	*98.5*	257	*64.3*	10.27	0.04	263.81	10.23
2004	0	100	0	-	92	*92.0*	0.00	0.01	0.00	-0.01
2005	900	100	798	*88.7*	69	*69.0*	0.12	0.01	11.57	0.11
2006	3,200	15,900	3,120	*97.5*	15,834	*99.6*	0.47	2.40	0.20	-1.92
Average*							**6.8**	**1.5**	**40.0**	**5.3**

VWC of Sheep (m3/animal) **151.41**

VWC of Mutton trade with U.S.

Year	Total Export *tonnes*	Total Imports *tonnes*	Total Exports (to US) *tonnes*	*Export to US as %* *of total export trade*	Total Imports (from US) *tonnes*	*Import from US as %* *of total import trade*	VWC (Exports to US) *Tm3*	VWC (Imports from US) *Tm3*	Ratio *VWC Imp / VWC Exp*	Difference *Tm3*
1989	140	12,400	36	*25.7*	302	*2.4*	50.1	420.7	8.4	-370.5
1990	40	14,500	19	*47.5*	1010	*7.0*	26.5	1,406.9	53.2	-1,380.4
1991	98	13,900	65	*66.3*	1210	*8.7*	90.5	1,685.4	18.6	-1,594.9
1992	24	12,200	0	*0.0*	1100	*9.0*	0.0	1,532.2	-	-1,532.2
1993	79	13,500	2	*2.5*	726	*5.4*	2.8	1,011.3	363.0	-1,008.5
1994	97	14,600	29	*29.9*	475	*3.3*	40.4	661.6	16.4	-621.2
1995	83	13,100	60	*72.3*	540	*4.1*	83.6	752.2	9.0	-668.6
1996	78	11,400	17	*21.8*	332	*2.9*	23.7	462.5	19.5	-438.8
1997	230	12,600	90	*39.1*	235	*1.9*	125.4	327.3	2.6	-202.0
1998	240	14,300	131	*54.6*	282	*2.0*	182.5	392.8	2.2	-210.3
1999	270	15,200	112	*41.5*	184	*1.2*	156.0	256.3	1.6	-100.3
2000	290	16,900	123	*42.4*	79	*0.5*	171.3	110.6	0.6	60.7
2001	300	18,300	106	*35.3*	175	*1.0*	147.7	243.8	1.7	-96.1
2002	280	17,500	160	*57.1*	149	*0.9*	222.9	207.5	0.9	15.3
2003	90	18,500	77	*85.6*	68	*0.4*	107.3	94.9	0.9	12.4
2004	310	18,500	150	*48.4*	271	*1.5*	208.9	377.5	1.8	-168.5
2005	260	19,300	120	*46.2*	425	*2.2*	167.2	592.0	3.5	-424.8
2006	230	22,800	120	*52.2*	814	*3.6*	167.2	1,133.8	6.8	-966.7
Average*							**129.0**	**473.1**	**30.8**	**-344.1**

VWC of Mutton (m3/ton) **1,393**

***Average values are for values from 1993-2006**

Source
Total Sheep and Mutton Export/Import: Sheep Statistics, 2007, Statistics Canada, Catalogue no. 23-011-XIE
Sheep and Mutton Export and Import 1989-2001 (US): Livestock Statistics, 2002, Statistics Canada, Cat No. 23-603-XIE; 2002-2006
Sheep and Mutton Export 2001-2006 (US): Red Meat Market Information, AAFC, Import/Export of cattle, sheep and hog from /to U.S. (1993-2006)
Sheep and Lamb/ Mutton Import: U.S. trade internet system: Foreign Agriculture Service, USDA

VWC of Broiler Chicken trade with U.S.

Year	Total Exports (to US)	Total Imports (from US)	VWC (Exports to US)	VWC (Imports from US)	Ratio	Difference
	head	*head*	*Tm3*	*Tm3*	*VWC Imp / VWC Exp*	*Tm3*
1990	272,079	4,471,646	1,017.6	16,724.4	16.44	-15,706.8
1991	306,434	4,537,723	1,146.1	16,971.5	14.81	-15,825.4
1992	87,010	4,762,735	325.4	17,813.1	54.74	-17,487.7
1993	101,114	4,738,819	378.2	17,723.7	46.87	-17,345.5
1994	125,566	10,932,060	469.6	40,887.0	87.06	-40,417.4
1995	52,678	12,435,175	197.0	46,508.8	236.06	-46,311.8
1996	229,312	16,295,175	857.6	60,945.6	71.06	-60,087.9
1997	535,412	18,934,057	2,002.5	70,815.3	35.36	-68,812.8
1998	516,272	25,428,925	1,930.9	95,106.7	49.25	-93,175.8
1999	440,375	20,467,535	1,647.0	76,550.6	46.48	-74,903.6
2000	640,316	17,525,536	2,394.8	65,547.3	27.37	-63,152.4
2001	348,646	21,901,470	1,304.0	81,913.7	62.82	-80,609.7
2002	309,161	21,621,334	1,156.3	80,866.0	69.94	-79,709.7
2003	277,555	17,245,824	1,038.1	64,501.1	62.13	-63,463.0
2004	409,850	16,604,399	1,532.9	62,102.1	40.51	-60,569.2
2005	1,732,870	17,899,567	6,481.1	66,946.2	10.33	-60,465.1
2006	1,134,742	9,289,192	4,244.0	34,742.5	8.19	-30,498.5
Average*			**1831.0**	**61796.9**	**61.0**	**-59965.9**

VWC of Chicken (m3/animal) **3.74**

VWC of Chicken Meat trade with U.S.

Year	Total Exports (to US)	Total Imports (from US)	VWC (Exports to US)	VWC (Imports from US)	Ratio	Difference
	tonnes	*tonnes*	*Mm3*	*Mm3*	*VWC Imp / VWC Exp*	*Mm3*
1996	2,030	49,697	2.5	61.7	24.48	-59.2
1997	2,762	59,668	3.4	74.1	21.61	-70.6
1998	4,037	75,356	5.0	93.5	18.67	-88.5
1999	6,241	74,515	7.7	92.5	11.94	-84.7
2000	6,958	86,683	8.6	107.6	12.46	-98.9
2001	11,095	84,507	13.8	104.9	7.62	-91.1
2002	12,302	99,932	15.3	124.0	8.12	-108.8
2003	11,795	84,243	14.6	104.5	7.14	-89.9
2004	16,405	91,392	20.4	113.4	5.57	-93.1
2005	19,765	88,098	24.5	109.3	4.46	-84.8
2006	28,522	92,270	35.4	114.5	3.24	-79.1
Average			**13.8**	**100.0**	**11.4**	**-86.2**

VWC of Chicken meat (m3/ton) **1241.03**

***Average values are for values from 1993-2006**

Source Chicken and Meat Export/Import: U.S. trade internet system: Foreign Agriculture Service, USDA

Appendix 6: Virtual Water flow Calculation for Alberta

Table 1: Trade of Livestock between Alberta and United States (in Canadian Dollars)

Non-Purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	527,152,154	600,358,403	690,351,961	746,768,689	658,091,043	696,337,606	465,970,922	511,764,197	712,557,838	635,123,367	196,204,670	0	272,955,786	697,172,671	**529,343,522**
Total Import	6,052,749	9,461,422	9,165,819	4,133,868	5,779,110	27,210,918	83,632,922	144,085,619	131,908,645	7,559,496	2,121,680	0	0	21,863	**30,795,294**
Trade Balance	521,099,405	590,896,981	681,186,142	742,634,821	652,311,933	669,126,688	382,338,000	367,678,578	580,649,193	627,563,871	194,082,990	0	272,955,786	697,150,808	**498,548,228**
Ratio (Exp/Imp)	**87.1**	**63.5**	**75.3**	**180.6**	**113.9**	**25.6**	**5.6**	**3.6**	**5.4**	**84.0**	**92.5**	**0.0**	**-**	**31888.2**	**2,510**

Purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	252,383	20,087	8,642	220,849	384,004	438,788	164,078	293,735	91,017	85,714	0	0	0	0	**139,950**
Total Import	940,252	985,764	1,011,525	1,483,534	3,550,277	1,636,966	1,270,472	1,330,317	1,424,448	465,692	232,703	0	12,000	90,023	**1,030,998**
Trade Balance	-687,869	-965,677	-1,002,883	-1,262,685	-3,166,273	-1,198,178	-1,106,394	-1,036,582	-1,333,431	-379,978	-232,703	0	-12,000	-90,023	**-891,048**
Ratio (Exp/Imp)	**0.3**	**0.0**	**0.0**	**0.1**	**0.1**	**0.3**	**0.1**	**0.2**	**0.1**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0**
Ratio (Imp/Exp)	**3.7**	**49.1**	**117.0**	**6.7**	**9.2**	**3.7**	**7.7**	**4.5**	**15.7**	**5.4**	**-**	**-**	**-**	**-**	**22**

Swine

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	16,010,011	18,872,501	51,254,288	72,567,897	61,082,172	85,874,519	72,554,245	92,345,916	123,592,782	75,728,197	54,067,683	73,143,409	68,757,894	54,807,880	**65,761,385**
Total Import	3,493	430,181	90,189	89,066	82,080	278,995	74,926	58,756	96,875	96,835	0	142,104	32,201	0	**105,407**
Trade Balance	16,006,518	18,442,320	51,164,099	72,478,831	61,000,092	85,595,524	72,479,319	92,287,160	123,495,907	75,631,362	54,067,683	73,001,305	68,725,693	54,807,880	**65,655,978**
Ratio (Exp/Imp)	**4583.5**	**43.9**	**568.3**	**814.8**	**744.2**	**307.8**	**968.3**	**1571.7**	**1275.8**	**782.0**	**-**	**514.7**	**2135.3**	**-**	**1,193**

Sheep

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	1,478,160	3,627,530	2,502,345	2,816,238	1,907,932	1,070,054	1,925,397	2,973,000	2,402,706	5,351,578	3,111,034	0	0	0	**2,083,284**
Total Import	156,093	502,546	851,161	451,884	200,918	646,317	396,766	57,492	60,125	9,325	6,902	0	0	1,623,343	**354,491**
Trade Balance	1,322,067	3,124,984	1,651,184	2,364,354	1,707,014	423,737	1,528,631	2,915,508	2,342,581	5,342,253	3,104,132	0	0	-1,623,343	**1,728,793**
Ratio (Exp/Imp)	**9.5**	**7.2**	**2.9**	**6.2**	**9.5**	**1.7**	**4.9**	**51.7**	**40.0**	**573.9**	**450.7**	**0.0**	**0.0**	**0.0**	**83**

Broiler Chicken

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	217,627	247,307	234,993	274,816	317,011	328,575	305,239	352,805	155,538	76,012	39,246	3,950	0	0	**182,366**
Total Import	149,427	120,036	414,944	550,460	500,561	276,540	673,080	907,217	691,234	761,380	589,526	623,602	368,772	498,714	**508,964**
Trade Balance	68,200	127,271	-179,951	-275,644	-183,550	52,035	-367,841	-554,412	-535,696	-685,368	-550,280	-619,652	-368,772	-498,714	**-326,598**
Ratio (Exp/Imp)	**1.5**	**2.1**	**0.6**	**0.5**	**0.6**	**1.2**	**0.5**	**0.4**	**0.2**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**1**
Ratio (Imp/Exp)	**0.69**	**0.49**	**1.77**	**2.00**	**1.58**	**0.84**	**2.21**	**2.57**	**4.44**	**10.02**	**15.02**	**157.87**	**-**	**-**	**17**

Beef-Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	255,643	328,270	322,695	427,750	586,550	793,469	1,006,014	1,052,731	1,254,167	1,235,823	867,869	1,173,105	1,141,402	675,683	**794,369**
Total Import	37,090	37,626	37,521	32,942	37,565	19,102	11,151	17,311	22,568	23,483	29,795	4,049	6,908	19,597	**24,051**
Trade Balance	218,553	290,644	285,174	394,809	548,985	774,367	994,863	1,035,421	1,231,599	1,212,340	838,074	1,169,056	1,134,493	656,086	**770,319**
Ratio (Exp/Imp)	**6.9**	**8.7**	**8.6**	**13.0**	**15.6**	**41.5**	**90.2**	**60.8**	**55.6**	**52.6**	**29.1**	**289.7**	**165.2**	**34.5**	**62**

Pork - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	64,660	67,229	89,789	112,363	112,962	60,193	65,597	86,996	85,876	41,260	44,549	103,364	126,810	129,890	**85,110**
Total Import	312	981	901	1,037	2,946	5,816	2,804	3,402	10,675	13,258	5,792	8,123	7,656	3,893	**4,828**
Trade Balance	64,348	66,248	88,888	111,326	110,015	54,377	62,793	83,593	75,202	28,002	38,757	95,241	119,154	125,997	**80,282**
Ratio (Exp/Imp)	**207.2**	**68.5**	**99.7**	**108.4**	**38.3**	**10.3**	**23.4**	**25.6**	**8.0**	**3.1**	**7.7**	**12.7**	**16.6**	**33.4**	**47**

Mutton - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	7,575	29,035	17,932	0	130,613	205,422	36,765	125,882	121,952	95,701	84,246	229,405	197,163	119,429	**100,080**
Total Import	65,187	10,271	4,268	0	0	0	544	0	111,731	199,789	0	0	310,138	223,132	**66,076**
Trade Balance	-57,612	18,764	13,664	0	130,613	205,422	36,221	125,882	10,221	-104,088	84,246	229,405	-112,975	-103,703	**34,004**
Ratio (Exp/Imp)	**0.1**	**2.8**	**4.2**				**67.6**		**1.1**	**0.5**			**0.6**	**0.5**	**10**

Milk (<2%, 2-6%, <6% fat)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Total Import	686	1,158	0	0	104	37	3,856	45	0	0	0	604,583	0	0	**43,605**
Trade Balance	-686	-1,158	0	0	-104	-37	-3,856	-45	0	0	0	-604,583	0	0	**-43,605**
Ratio (Exp/Imp)	**0.0**	**0.0**			**0.0**	**0.0**	**0.0**	**0.0**				**0.0**			**0**

Chicken Meat - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	1,719	0	0	14,748	59,568	11,102	27,346	103,966	532,206	1,037,823	1,030,113	188,827	89,578	178,003	**233,929**
Total Import	347,961	343,363	129,046	1,020,634	1,492,340	2,354,037	2,164,543	1,840,345	1,799,223	2,975,530	4,737,499	4,461,018	4,745,473	4,322,086	**2,338,078**
Trade Balance	-346,242	-343,363	-129,046	-1,005,886	-1,432,772	-2,342,935	-2,137,197	-1,736,379	-1,267,017	-1,937,707	-3,707,386	-4,272,191	-4,655,895	-4,144,083	**-2,104,150**
Ratio (Exp/Imp)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.3**	**0.3**	**0.2**	**0.0**	**0.0**	**0.0**	**0**
Ratio (Imp/Exp)	**202.42**			**69.20**	**25.05**	**212.04**	**79.15**	**17.70**	**3.38**	**2.87**	**4.60**	**23.62**	**52.98**	**24.28**	**59.77**

Source: Total Export, Import and Trade Balance: Trade Data Online, Industry Canada, http://strategis.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php#tag

Table 2: VWC calculation for Trade of Livestock between Alberta and United States (in Canadian Dollars)

Non-purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	527,152,154	600,358,403	690,351,961	746,768,689	658,091,043	696,337,606	465,970,922	511,764,197	712,557,838	635,123,367	196,204,670	0	272,955,786	697,172,671	
Total Import	6,052,749	9,461,422	9,165,819	4,133,868	5,779,110	27,210,918	83,632,922	144,085,619	131,908,645	7,559,496	2,121,680	0	0	21,863	
Prices (cwt)	91.90	86.17	82.91	78.42	84.00	83.56	89.30	95.00	102.82	98.88	84.28	78.40	85.62	86.90	
Total Export (head)	470,176	571,077	682,502	780,548	642,165	683,064	427,708	441,557	568,045	526,490	190,820	0	261,311	657,598	
Total Import (head)	5,399	9,000	9,062	4,321	5,639	26,692	76,765	124,319	105,156	6,266	2,063	0	0	21	
VWC in Exports to US	1,291,290,724	1,568,404,421	1,874,421,275	2,143,694,134	1,763,641,262	1,875,966,056	1,174,656,577	1,212,690,153	1,560,077,162	1,445,949,717	524,068,879	0	717,663,136	1,806,026,570	
VWC in Imports from US	14,826,571	24,717,462	24,886,735	11,866,792	15,487,640	73,307,485	210,828,524	341,429,143	288,801,349	17,210,280	5,667,074	0	0	56,636	
Ratio (Exp/Imp)	**87**	**63**	**75**	**181**	**114**	**26**	**6**	**4**	**5**	**84**	**92**	**0**	**-**	**31,888**	**2,510**
Difference	**1,276,464,153**	**1,543,686,959**	**1,849,534,540**	**2,131,827,342**	**1,748,153,622**	**1,802,658,571**	**963,828,052**	**871,261,010**	**1,271,275,813**	**1,428,739,437**	**518,401,804**	**0**	**717,663,136**	**1,805,969,934**	**1,280,676,027**

VWC of Beef Cattle (m3/animal) 2746.40

Swine

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	16,010,011	18,872,501	51,254,288	72,567,897	61,082,172	85,874,519	72,554,245	92,345,916	123,592,782	75,728,197	54,067,683	73,143,409	68,757,894	54,807,880	
Total Import	3,493	430,181	90,189	89,066	82,080	278,995	74,926	58,756	96,875	96,835	0	142,104	32,201	0	
Prices (cwt)	68.04	63.05	66.22	82.10	81.19	53.07	56.70	75.30	78.02	63.96	64.86	75.75	68.47	61.18	
Total Export (head)	98,043	124,719	322,500	368,290	313,473	674,224	533,173	510,989	660,049	493,330	347,336	402,329	418,419	373,269	
Total Import (head)	21	2,843	567	452	421	2,190	551	325	517	631	0	782	196	0	
VWC in Exports to US	9,085,288	11,557,283	29,884,941	34,128,151	29,048,473	62,477,926	49,407,303	47,351,539	61,164,375	45,715,191	32,186,384	37,282,407	38,773,376	34,589,550	
VWC in Imports from US	1,982	263,437	52,587	41,887	39,034	202,983	51,022	30,128	47,942	58,457	0	72,433	18,159	0	
Ratio (VWC Exp/Imp)	**4,583**	**44**	**568**	**815**	**744**	**308**	**968**	**1,572**	**1,276**	**782**	**-**	**515**	**2,135**	**-**	**1,192.5**
Difference in VW trade	**9,083,306**	**11,293,845**	**29,832,355**	**34,086,264**	**29,009,439**	**62,274,944**	**49,356,280**	**47,321,411**	**61,116,432**	**45,656,734**	**32,186,384**	**37,209,974**	**38,755,217**	**34,589,550**	**37,269,438**

VWC of Swine (m3/animal) 92.67

Sheep

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	1,478,160	3,627,530	2,502,345	2,816,238	1,907,932	1,070,054	1,925,397	2,973,000	2,402,706	5,351,578	3,111,034	0	0	0	
Total Import	156,093	502,546	851,161	451,884	200,918	646,317	396,766	57,492	60,125	9,325	6,902	0	0	1,623,343	
Prices (per 100 lbs)	76.27	87.66	91.05	108.20	108.11	94.52	93.88	99.40	86.89	88.40	89.95	83.18	109.69	115.00	
Total Export (head)	19,381	41,382	27,483	26,028	17,648	11,321	20,509	29,909	27,652	60,538	34,586	0	0	0	
Total Import (head)	2,047	5,733	9,348	4,176	1,858	6,838	4,226	578	692	105	77	0	0	14,116	
VWC in Exports to US	2,934,327	6,265,422	4,161,098	3,940,786	2,672,008	1,714,047	3,105,188	4,528,447	4,186,698	9,165,799	5,236,539	0	0	0	
VWC in Imports from US	309,864	867,991	1,415,378	632,325	281,380	1,035,291	639,885	87,571	104,767	15,971	11,618	0	0	2,137,240	
Ratio (VWC Exp/Imp)	**9**	**7**	**3**	**6**	**9**	**2**	**5**	**52**	**40**	**574**	**451**	**0**	**0**	**0**	**82.73**
Difference in VW trade	**2624463.1**	**5397430.8**	**2745720.1**	**3308460.8**	**2390627.8**	**678755.6**	**2465303.1**	**4440875.5**	**4081930.1**	**9149828.1**	**5224921.4**	**0.0**	**0.0**	**-2137239.5**	**2,883,648.35**

VWC of Sheep(m3/animal) 151.41

Source:
Price of Non-Purebred Cattle (per 100 wt/cwt): Cattle Statistics, 2007, Statistics Canada, Catalogue no. 23-012-XIE
Price of Sheep (per 100 lbs): Alberta Agriculture, Food, and Rural Development
URL: http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/ba3468a2a8681f69872569d60073fde1/9040f03cf1285b5a872570960078ceaf/$FILE/table62&63.pdf
Price of Hog (per 100 wt/cwt): Hog Statistics, 2007, Statistics Canada, Catalogue no. 23-010-XIE

Appendix 7: Virtual Water flow Calculation for Ontario

Table 1: Trade of Livestock between Ontario and United States (in Canadian Dollars)

Non-Purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	149,183,632	118,643,498	145,864,278	163,639,248	158,632,773	205,809,349	212,938,172	224,561,744	352,985,879	343,838,674	141,173,093	0	40,388,581	41,488,888	**164,224,844**
Total Import	24,795,270	36,202,508	24,945,301	17,504,329	18,699,861	27,342,191	38,964,546	51,090,238	36,615,816	38,286,098	16,750,935	1,133,633	1,009,051	11,155,869	**24,606,832**
Trade Balance	124,388,362	82,440,990	120,918,977	146,134,919	139,932,912	178,467,158	173,973,626	173,471,506	316,370,063	305,552,576	124,422,158	-1,133,633	39,379,530	30,333,019	**139,618,012**
Ratio (Exp/Imp)	**6.0**	**3.3**	**5.8**	**9.3**	**8.5**	**7.5**	**5.5**	**4.4**	**9.6**	**9.0**	**8.4**	**0.0**	**40.0**	**3.7**	**8.7**

Purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	1,330,522	756,972	686,629	494,488	724,611	2,312,101	8,732,656	8,542,669	12,444,153	10,137,344	4,886,644	0	0	0	**3,646,342**
Total Import	711,033	444,218	296,907	769,648	1,223,765	267,303	316,436	282,806	327,965	847,837	644,633	0	486,702	569,963	**513,515**
Trade Balance	619,489	312,754	389,722	-275,160	-499,154	2,044,798	8,416,220	8,259,863	12,116,188	9,289,507	4,242,011	0	-486,702	-569,963	**3,132,827**
Ratio (Exp/Imp)	**1.9**	**1.7**	**2.3**	**0.6**	**0.6**	**8.6**	**27.6**	**30.2**	**37.9**	**12.0**	**7.6**	**0.0**	**0.0**	**0.0**	**9.4**

Swine

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	27,367,441	30,663,352	59,135,302	139,330,697	193,811,940	159,064,774	81,554,325	114,805,855	145,721,513	129,483,150	185,603,003	246,047,536	207,850,718	189,788,755	**136,444,883**
Total Import	40,685	3,614	47,440	48,827	48,479	32,575	102,280	232,168	67,211	11,648	139,551	141,379	56,174	274,550	**89,042**
Trade Balance	27,326,756	30,659,738	59,087,862	139,281,870	193,763,461	159,032,199	81,452,045	114,573,687	145,654,302	129,471,502	185,463,452	245,906,157	207,794,544	189,514,205	**136,355,841**
Ratio (Exp/Imp)	**672.7**	**8484.6**	**1246.5**	**2853.6**	**3997.9**	**4883.0**	**797.4**	**494.5**	**2168.1**	**11116.3**	**1330.0**	**1740.3**	**3700.1**	**691.3**	**3,155.4**

Sheep

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	44,959	91,814	81,061	87,642	96,767	99,884	26,448	220,419	1,853,632	3,400,330	1,937,690	0	82,469	0	**573,080**
Total Import	870,203	1,359,018	1,518,779	2,065,875	955,029	929,482	576,167	245,726	230,779	44,607	29,698	30,199	53,679	4,484	**636,695**
Trade Balance	-825,244	-1,267,204	-1,437,718	-1,978,233	-858,262	-829,598	-549,719	-25,307	1,622,853	3,355,723	1,907,992	-30,199	28,790	-4,484	**-63,615**
Ratio (Exp/Imp)	**0.1**	**0.1**	**0.1**	**0.0**	**0.1**	**0.1**	**0.0**	**0.9**	**8.0**	**76.2**	**65.2**	**0.0**	**1.5**	**0.0**	**10.9**
Ratio (Imp/Exp)	**19.4**	**14.8**	**18.7**	**23.6**	**9.9**	**9.3**	**21.8**	**1.1**	**0.1**	**0.0**	**0.0**	**-**	**0.7**	**-**	**9.9**

Broiler Chicken

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	759,496	916,732	1,155,800	2,311,914	4,648,188	3,296,568	1,540,920	890,280	618,301	2,953,551	4,949,989	7,431,602	7,735,872	4,876,742	**3,148,997**
Total Import	21,644,572	20,655,170	13,696,247	12,597,568	18,429,698	23,225,135	13,568,600	13,092,122	14,768,774	15,171,267	11,865,908	10,420,155	10,605,176	9,328,277	**14,933,476**
Trade Balance	-20,885,076	-19,738,438	-12,540,447	-10,285,654	-13,781,510	-19,928,567	-12,027,680	-12,201,842	-14,150,473	-12,217,716	-6,915,919	-2,988,553	-2,869,304	-4,451,535	**-11,784,480**
Ratio (Exp/Imp)	**0.0**	**0.0**	**0.1**	**0.2**	**0.3**	**0.1**	**0.1**	**0.1**	**0.0**	**0.2**	**0.4**	**0.7**	**0.7**	**0.5**	**0.3**
Ratio (Imp/Exp)	**28.5**	**22.5**	**11.9**	**5.4**	**4.0**	**7.0**	**8.8**	**14.7**	**23.9**	**5.1**	**2.4**	**1.4**	**1.4**	**1.9**	**9.9**

Beef-Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	104,554	88,803	91,065	102,372	135,267	162,911	196,583	214,578	230,541	276,577	224,545	275,562	282,639	257,387	**188,813**
Total Import	209,313	253,453	315,418	275,691	261,076	267,708	247,663	260,663	251,973	254,959	254,096	56,580	135,688	317,819	**240,150**
Trade Balance	-104,759	-164,650	-224,353	-173,318	-125,810	-104,797	-51,080	-46,085	-21,432	21,619	-29,551	218,983	146,951	-60,431	**-51,337**
Ratio (Exp/Imp)	**0.5**	**0.4**	**0.3**	**0.4**	**0.5**	**0.6**	**0.8**	**0.8**	**0.9**	**1.1**	**0.9**	**4.9**	**2.1**	**0.8**	**1.1**
Ratio (Imp/Exp)	**2.0**	**2.9**	**3.5**	**2.7**	**1.9**	**1.6**	**1.3**	**1.2**	**1.1**	**0.9**	**1.1**	**0.2**	**0.5**	**1.2**	**1.6**

Pork - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	80,481	86,468	102,348	107,810	86,358	84,453	125,952	188,506	251,646	232,708	263,021	326,463	334,041	277,946	**182,014**
Total Import	19,358	22,596	25,187	45,322	79,725	62,348	52,805	65,331	94,364	99,735	104,871	154,363	222,168	237,696	**91,848**
Trade Balance	61,122	63,872	77,161	62,488	6,633	22,105	73,147	123,175	157,282	132,972	158,150	172,100	111,873	40,250	**90,166**
Ratio (Exp/Imp)	**4.2**	**3.8**	**4.1**	**2.4**	**1.1**	**1.4**	**2.4**	**2.9**	**2.7**	**2.3**	**2.5**	**2.1**	**1.5**	**1.2**	**2.5**

Mutton - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	6,407	355,511	1,319,269	1,001,273	1,163,751	1,425,870	2,096,198	1,281,601	903,295	1,199,074	65,274	6,441	1,047,212	84,036	**853,944**
Total Import	1,785,715	1,558,379	1,687,749	1,369,607	1,049,909	1,315,226	859,592	403,491	365,228	835,546	306,661	1,006,933	1,406,632	1,680,817	**1,116,535**
Trade Balance	-1,779,308	-1,202,868	-368,480	-368,334	113,842	110,644	1,236,606	878,110	538,067	363,528	-241,387	-1,000,492	-359,420	-1,596,781	**-262,591**
Ratio (Exp/Imp)	**0.0**	**0.2**	**0.8**	**0.7**	**1.1**	**1.1**	**2.4**	**3.2**	**2.5**	**1.4**	**0.2**	**0.0**	**0.7**	**0.0**	**1.0**
Ratio (Imp/Exp)	**278.7**	**4.4**	**1.3**	**1.4**	**0.9**	**0.9**	**0.4**	**0.3**	**0.4**	**0.7**	**4.7**	**156.3**	**1.3**	**20.0**	**33.7**

Milk (<2%, 2-6%, <6% fat)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	0	0	0	0	0	408,495	1,335,119	263,143	1,159,563	2,753,951	2,140,259	1,880,358	2,577,369	1,017,680	**966,853**
Total Import	45,379	1,820	18,436	7,704	5,291	43,240	7,017	18	4,129	59,167	636,781	3,413,886	5,877,105	4,044,927	**1,011,779**
Trade Balance	-45,379	-1,820	-18,436	-7,704	-5,291	365,255	1,328,102	263,125	1,155,434	2,694,784	1,503,478	-1,533,528	-3,299,736	-3,027,247	**-44,926**
Ratio (Exp/Imp)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**9.4**	**190.3**	**14619.1**	**280.8**	**46.5**	**3.4**	**0.6**	**0.4**	**0.3**	**1,082.2**
Ratio (Imp/Exp)	**-**	**-**	**-**	**-**	**-**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**1.8**	**2.3**	**4.0**	**0.9**

Chicken Meat - Fresh, Chilled or Frozen

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	274	403	1,114	2,956	3,675	6,994	13,561	17,854	26,296	28,046	38,732	29,778	25,396	19,330	**15,315**
Total Import	10,929	16,917	15,155	148,934	191,404	248,076	233,128	252,318	286,981	292,792	265,873	276,466	246,709	254,223	**195,708**
Trade Balance	-10,655	-16,514	-14,041	-145,978	-187,729	-241,082	-219,567	-234,464	-260,686	-264,746	-227,140	-246,688	-221,313	-234,893	**-180,393**
Ratio (Exp/Imp)	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Ratio (Imp/Exp)	**39.9**	**42.0**	**13.6**	**50.4**	**52.1**	**35.5**	**17.2**	**14.1**	**10.9**	**10.4**	**6.9**	**9.3**	**9.7**	**13.2**	**23.2**

Source: Export, Import and Trade Balance:Trade Data Online, Industry Canada, http://strategis.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php#tag

Table 2: Trade of Livestock between Ontario and United States (in Canadian Dollars)

Non-Purebred Cattle

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	149,183,632	118,643,498	145,864,278	163,639,248	158,632,773	205,809,349	212,938,172	224,561,744	352,985,879	343,838,674	141,173,093	0	40,388,581	41,488,888	
Total Import	24,795,270	36,202,508	24,945,301	17,504,329	18,699,861	27,342,191	38,964,546	51,090,238	36,615,816	38,286,098	16,750,935	1,133,633	1,009,051	11,155,869	
Prices (cwt)	97.23	92.58	88.12	82.89	85.85	88.26	92.64	102.86	110.90	103.21	84.70	77.00	90.87	93.30	
Total Export (head)	125,765	100,019	122,967	137,952	133,731	173,502	179,512	189,311	297,576	289,864	119,012	0	34,049	34,976	
Total Import (head)	20,903	30,520	21,029	14,757	15,764	23,050	32,848	43,070	30,868	32,276	14,121	956	851	9,405	
VWC in Exports to US	345,401,682	274,692,761	337,716,452	378,870,461	367,279,076	476,505,997	493,011,208	519,923,017	817,260,678	796,082,349	326,855,052	0	93,510,820	96,058,338	
VWC in Imports from US	57,407,960	83,818,895	57,755,323	40,527,400	43,295,389	63,304,792	90,213,782	118,288,138	84,775,818	88,642,986	38,783,083	2,624,676	2,336,234	25,828,946	
Ratio (VWC Exp/Imp)	**6.0**	**3.3**	**5.8**	**9.3**	**8.5**	**7.5**	**5.5**	**4.4**	**9.6**	**9.0**	**8.4**	**0.0**	**40.0**	**3.7**	**8.65**
Difference in VW trade	**287,993,722**	**190,873,866**	**279,961,129**	**338,343,061**	**323,983,687**	**413,201,205**	**402,797,426**	**401,634,878**	**732,484,860**	**707,439,363**	**288,071,969**	**-2,624,676**	**91,174,586**	**70,229,392**	**323,254,605**

VWC of Beef Cattle (m3/animal) 2746.40

Swine

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	27,367,441	30,663,352	59,135,302	139,330,697	193,811,940	159,064,774	81,554,325	114,805,855	145,721,513	129,483,150	185,603,003	246,047,536	207,850,718	189,788,755	
Total Import	40,685	3,614	47,440	48,827	48,479	32,575	102,280	232,168	67,211	11,648	139,551	141,379	56,174	274,550	
Prices (cwt)	68.95	65.77	68.49	85.73	84.82	54.88	54.43	73.48	78.47	62.60	60.78	72.57	67.66	59.43	
Total Export (head)	165,382	194,259	359,756	677,178	952,075	1,207,671	624,306	651,004	773,764	861,842	1,272,369	1,412,702	1,279,995	1,330,618	
Total Import (head)	246	23	289	237	238	247	783	1,317	357	78	957	812	346	1,925	
VWC in Exports to US	15,325,382	18,001,271	33,337,347	62,751,681	88,225,400	111,910,616	57,852,222	60,326,241	71,702,021	79,863,861	117,905,939	130,910,136	118,612,624	123,303,704	
VWC in Imports from US	22,783	2,122	26,744	21,991	22,068	22,918	72,554	121,996	33,071	7,184	88,651	75,221	32,056	178,372	
Ratio (VWC Exp/Imp)	**673**	**8,485**	**1,247**	**2,854**	**3,998**	**4,883**	**797**	**494**	**2,168**	**11,116**	**1,330**	**1,740**	**3,700**	**691**	**3,155.45**
Difference in VW trade	**15302598.6**	**17999149.1**	**33310602.4**	**62729690.2**	**88203332.2**	**111887698.0**	**57779667.1**	**60204245.6**	**71668949.9**	**79856676.2**	**117817287.7**	**130834915.1**	**118580567.4**	**123125332.1**	**77,807,194**

VWC of Sheep (m3/animal) 92.67

Sheep

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Total Export	44,959	91,814	81,061	87,642	96,767	99,884	26,448	220,419	1,853,632	3,400,330	1,937,690	0	82,469	0	
Total Import	870,203	1,359,018	1,518,779	2,065,875	955,029	929,482	576,167	245,726	230,779	44,607	29,698	30,199	53,679	4,484	
Prices (cwt)	110.67	116.43	127.17	135.11	140.06	132.10	124.13	132.83	123.00	116.09	120.31	106.44	148.51	160.78	
Total Export (head)	406	789	637	649	691	756	213	1,659	15,070	29,290	16,106	0	555	0	
Total Import (head)	7,863	11,672	11,943	15,290	6,819	7,036	4,642	1,850	1,876	384	247	284	361	28	
VWC in Exports to US	61,507	119,395	96,509	98,212	104,605	114,481	32,259	251,243	2,281,703	4,434,728	2,438,503	0	84,077	0	
VWC in Imports from US	1,190,506	1,767,262	1,808,217	2,315,034	1,032,389	1,065,317	702,769	280,089	284,074	58,177	37,374	42,956	54,725	4,223	
Ratio (VWC Imp/Exp)	**19**	**15**	**19**	**24**	**10**	**9**	**22**	**1**	**0**	**0**	**0**	**-**	**1**	**-**	**9.95**
Diff. in VW (Imp-Exp)	**1128998.1**	**1647867.9**	**1711708.4**	**2216821.4**	**927783.2**	**950836.0**	**670509.2**	**28846.0**	**-1997628.9**	**-4376551.5**	**-2401129.4**	**42956.5**	**-29351.3**	**4222.5**	**37,563.43**

VWC of Sheep(m3/animal) 151.41

Source: Price of Non-Purebred Cattle (per 100 wt/cwt): Cattle Statistics, 2007, Statistics Canada, Catalogue no. 23-012-XIE
Price of Hog (per 100 wt/cwt): Hog Statistics, 2007, Statistics Canada, Catalogue no. 23-010-XIE