University of Alberta

BSE Impacts on the Canadian Beef Industry-An Application of the Social Amplification of Risk Framework to Consumer and Producer Behaviour

by

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Abstract

In this study the dynamics of risk perceptions about BSE held by Canadian consumers and cow-calf operators are evaluated. Since the BSE outbreak in 2003, Canadian consumers and cow-calf operators may have had various different reactions to BSE. These reactions may be related to their different levels of risk perception about BSE, risk perceptions which may have evolved over time and may be affected by BSE media information. These reactions may also be the result of factors other than BSE. An analysis of behavioural models of consumers and cow-calf producers is required to reveal the impacts of both BSE risk perceptions and non-BSE related factors.

In this study, the risk perceptions about BSE are specified applying a Social Amplification of Risk Framework (SARF) and a Prospective Reference Theory (PRT), and evaluated through market observed behaviour of Canadian consumers and cow-calf producers, an approach which is different than the traditional stated preference approach to eliciting risk perception measures. Parametric and non-parametric structural break tests associated with the BSE outbreak (May 2003) are employed to evaluate changes in consumers or cow-calf operators' behaviour.

The results show that SARF is supported by both panel data and time series data on Canadian consumers and cow-calf producers, suggesting that their risk perceptions about BSE are amplified by both the quantity and quality of BSE information. Risk perceptions about BSE have led to a decrease in beef demand and an increase in slaughter cow supply, which in turn, exacerbated losses in Canadian beef sector.

Structural break tests related to the BSE outbreak in May 2003 confirm changes in both consumers' and cow-calf producers' behaviour. Consumers with different profiles had different levels of risk perceptions about BSE and different demand and substitution elasticities. Cow-calf producers from different regions also had different levels of risk perceptions about BSE and different supply elasticities, suggesting the need for more analysis of market segmentation. Simulation analyses over the North American beef sector further confirmed the impact of BSE risk perceptions of Canadian consumers and cow-calf producers in the North American beef and live cattle market.

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1.1 BSE's Worldwide Impacts and Media

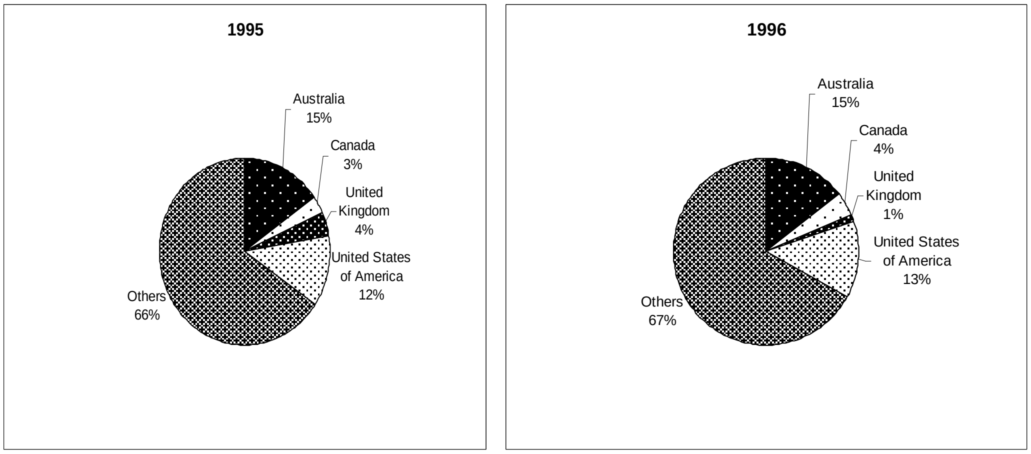
BSE or "Mad Cow Disease" is a deadly animal disease affecting the nervous system of cattle, which is believed to have a link to human variant Creutzfeldt - Jakob Disease (vCJD) (Public Health Agency of Canada, 2007). People may contract vCJD from eating BSE-contaminated beef. It is impossible currently to cure either Mad Cow Disease (Canadian Food Inspection Agency, 2005; 2006b) or human vCJD (Public Health Agency of Canada, 2007).

BSE-contamination is connected to an abnormal protein called a "prion", which presents when the "meat and bone meal" recovered from rendering dead cattle and waste carcasses is fed back to cattle (WHO, 2002). The prion causing BSE is concentrated in certain parts of the cattle carcass called Specified Risk Materials (SRMs) including the skull, brain, etc. The removal of SRMs at the time of slaughter can reduce the potential risk of transmission of BSE to animals or humans.

The first case of BSE was reported in England in November 1986. By 1989, BSE cases had been identified in Ireland, followed by cases in Portugal in 1990 and in France in 1991. In the United Kingdom, incidence of the BSE disease peaked in 1992 with nearly 40,000 cases, but declined thereafter (Herrmann et al., 2002). Until 1996, the economic cost of BSE in England was small and there was no evidence of transmission of BSE from animals to humans. However, a big loss in beef sales occurred after the Secretary of State's announcement of the possible relationship between BSE and new vCJD on 20 March 1996. Shortly after the announcement, beef sales in England decreased by 40% (DTZ Pieda, 1998). At the same time, the BSE risk was also felt in other European countries. Beef consumption in Italy fell 50% between April and May, 1996, Germany 40% and France 30% (Palmer, 1996). It is probable that the panic about the BSE threat might have also spread to countries outside of Europe, such as Canada. Lomeli (2005, page 100 and 131) found Canadians didn't react to BSE in beef consumption based on time series data but they did react to aggregate food safety information including BSE, Escherichia coli and Salmonella by decreasing beef consumption, based on cross sectional data in 1996 and 2001. BSE information is suspected to be a contributing factor to a higher beef demand elasticity with respect to food safety information in 1996 as compared to that in 2001.

Until June 30, 2008, 190,373 cases of BSE had been reported in the world. Of these, 184,576 cases of BSE were from UK, 5,797 cases of BSE were from Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Liechtenstein, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, United States of America. Among the 5,797 cases of BSE confirmed outside of UK, 5,517 cases were from eight countries — Belgium, France, Germany, Ireland, Italy, Portugal, Spain, Switzerland (OIE, 2008). In terms of human variant CJD, 208 patients from 11 countries had been identified by June 30, 2008: 167 from the United Kingdom, 23 from France, 4 from Ireland, 3 from the United States, 3 from Spain, 2 in the Netherlands, 2 in Portugal, and one each from Canada, Italy, Japan, and Saudi Arabia (CDC, 2008). The detection of BSE and vCJD has had a big impact on international trade in beef products and live cattle. The countries free of BSE enjoy additional international market share lost by countries with BSE. One example is that when the possible relationship between BSE and vCJD was claimed in 1996, the international market share for British beef dropped from 4% to 1%. At the same time, U.S. and Canada gained around 1 percent more each in their international beef market shares (Figure 1.1). The threat of BSE forced many countries to adopt feed bans, more BSE testing and beef cow tracking systems.

Figure 1.1 1995-1996 International Bovine Meat (including cattle and buffalo) Exports



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Media coverage and description during the BSE crisis might have played a critical role in the construction of risk perceptions. The mass media coverage of the BSE crisis in UK reached a peak in 1990. Media interest in BSE then decreased significantly until 1996 when the relationship between BSE and human vCJD was identified. In 1996, BSE became the major risk story again in the British media. From a quantitative aspect, the media coverage of the BSE crisis in UK did not match the real incidence of BSE (Eldridge and Reilly, 2003). From a qualitative aspect, British journalists' framing of the BSE story, imperfect communication between scientists and journalists, disbelief in government announcements, all contributed to an enlarged risk perception of BSE. Both the quantitative and qualitative effects of British media coverage could have created a *scare* among people (Miller and Reilly, 1995; Kitzinger and Reilly, 1997; Eldridge and Reilly, 2003). British consumers' confidence in beef and beef products plummeted and demand for beef decreased rapidly and didn't return to the pre-1996 level until 1999 (ElAmin, 2006).

1.2 BSE in Canada

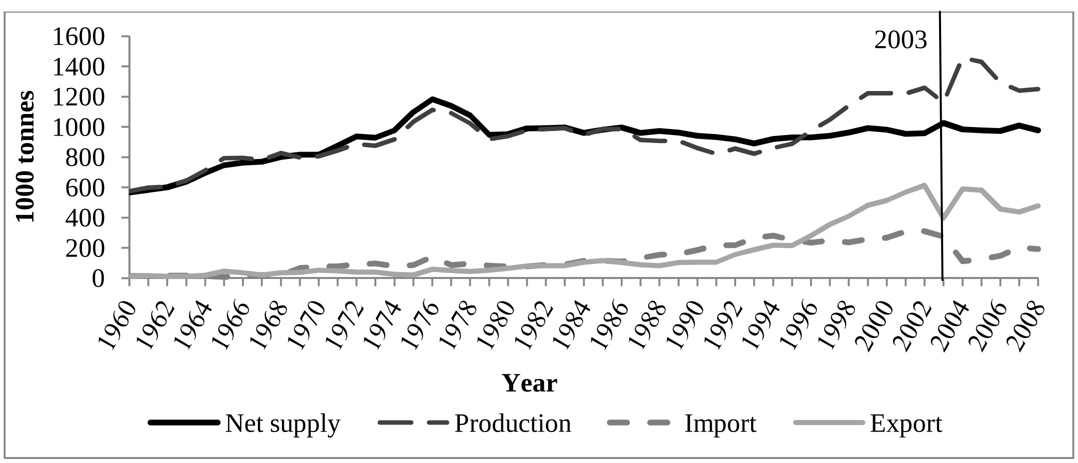
The first case of BSE in Canada was found in 1993 from a beef cow imported from Britain in 1987. The animal was destroyed and additional actions were taken immediately to deal with the risk that Canadian cattle might have been affected. A national BSE surveillance program was implemented, a program aimed at determining and monitoring the level of BSE present in Canada and confirming the effectiveness of the measures put into effect to protect human and animal health from the disease. The second case of BSE was reported on May 20, 2003, leading to border closures by other countries to Canadian beef products and live cattle. The third and fourth cases were confirmed on January, 2 and 11, 2005, respectively. The fifth to ninth cases were confirmed on January 23, April 16, July 4, July 13, and August 23, 2006 respectively. The tenth and eleventh cases were found on February 7 and May 2, 2007. The twelfth and thirteenth cases of BSE were found in June 23 and August 15, 2008. After each case was discovered, the feeds employed on the farms were examined and identified in terms of sources and production methods. The cattle in the same facilities as the BSE-contaminated cattle over a year period and the offspring of the BSE-contaminated cattle were also examined and tracked (Canadian Food Inspection Agency, 2006a).

In response to the BSE problem, since 1997, Canada has ruled out the practice of feeding the rendered protein from ruminant animals to all ruminants (Forge, 2005). In 2001, the Canadian Cattle Identification Program was established for cattle and bison, making it possible to trace individual animal from birth to slaughter. Also, in December 2000, the imports of rendered protein from suspicious origins were suspended (Canadian Food Inspection Agency, 2005; 2006a). Given these strong policies, among the thirteen cases of BSE found in Canada, seven cases were from cows born after the feed ban was imposed, one case was from a cow whose age was uncertain. Some possible explanations for that include the lagged response in compliance to the feed ban, cross contamination during feed production, distribution and storage, or any inappropriate use of feeds on farms. As a result, the Canadian government enhanced stricter feed controls in 2007 by banning the use of specified risk materials (SRMs) in all livestock feed, pet food and fertilizers (Canadian Food Inspection Agency, 2007). Although the enhanced feed ban can eliminate most of the potential risks of feed contamination, it generates additional issues about how to collect, destroy and dispose of SRMs. In the short term, SRMs can be managed either by burial in landfills or by incineration in rendering plants. Alternative uses of SRMs such as generating biofuel may be possible. It is of high importance to design suitable policies for SRM treatment (Health Canada, 2003). Currently, SRMs are still buried in landfills, which is not economical and bad for environment (Ma et al., 2007).

1.2.1 BSE Impacts on the Canadian Beef Industry

BSE had a big impact on the Canadian beef industry. Before the BSE discovery in 2003, the Canadian beef industry had had rapid growth in production and exports. By 2002, the production of beef reached 1256.16 thousand tonnes, 28.4% higher than in 1981, and the exports of beef was 612.63 thousand tonnes in 2002, around 7 times higher than in 1981. The expansion of production and exports stimulated growth in Canadian cattle inventories. The total cattle inventory on January 1, 2002 was 13761.5 thousand head, 13 percent higher than on January 1, 1981 (CANSIM II, 2006). In the first half of 2003, production and exports were still rising. However, after one case of BSE was discovered in an Alberta cow in May 2003, exports of beef decreased dramatically, leading to extra beef supply in the domestic market. The extra domestic beef supply resulted in lower beef prices and contributed to an increase in domestic beef disappearance in 2003. The situation of oversupply was alleviated partially in 2004 due to a partial recovery in beef and cattle exports and a continued decrease in beef imports. The general trends in production, net supply, exports and imports for Canadian beef are shown in Figure 1.2.

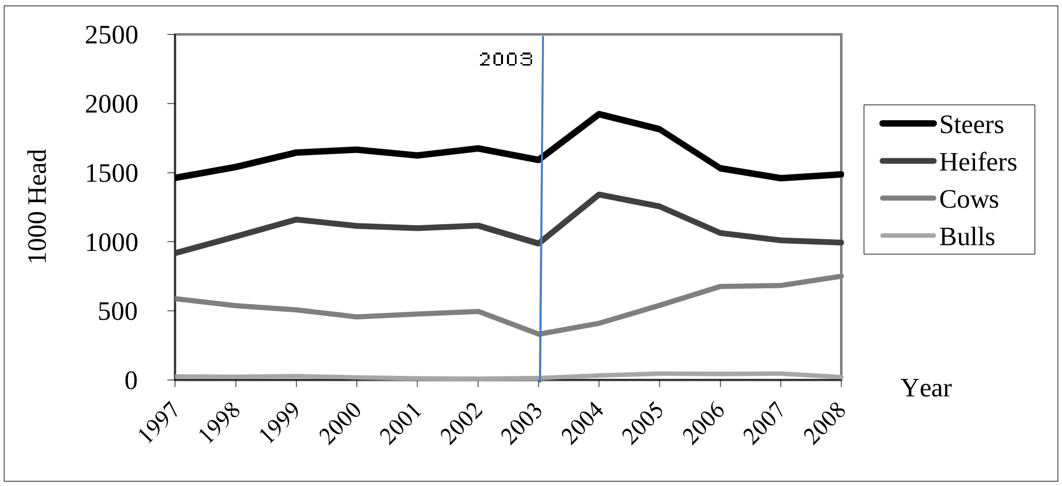
Figure 1.2 Beef Production, Net Supply, Imports and Exports in Canada



Source: CANSIMII Table 20010.

A temporary decrease in beef production in Canada[1] is shown in Figure 1.2. As compared to 2002, Canadian beef exports went down 35% and beef production went down 9% in 2003 (CANSIM II, 2006). The decrease in beef production is due to the fact that the number of slaughter cattle, especially that of slaughter steers, heifers and slaughter cows, declined in the second quarter of 2003. The decreased number of steers, heifers and cows slaughtered might be related to government policies for alleviating the slaughter burden, holdback behaviour of cattle producers facing low prices, or the reduced demand for slaughter cattle from processors. The annual number of slaughter cattle in Canada is shown in Figure 1.3.

Figure 1.3 Cattle Slaughtered in Federally Inspected Plants in Canada 1997-2008



Source: The slaughter numbers in federally inspected plants are from Red Meat Market Information, AAFC.

The border closures for Canadian beef and live cattle have had impacts on processors, feedlots and cow-calf producers. Because beef exports account for a big percentage of Canadian processors' sales, the loss of beef exports led to a decrease in slaughter demand. Slaughter numbers of cows, steers and heifers were well below the level of 2002 in the second half of 2003 and only returned to the 2002-year level in early 2004. The decreased demand for slaughter cattle led to cattle inventory increases in Canada. Cattle inventories in July 2003 reached 15738.2 thousand head, about 17% higher than in January 2003. According to Statistics Canada, farm incomes declined 48% between July and December 2003 as compared to the same period in 2002. The government program payments only

[1] The production of beef in Canada in 2004 returned to a level higher than that in 2002.

partially offset the economic losses in 2003 (Statistics Canada, 2004a). Due to poor expectations for the beef market, some producers gave up the idea of expanding their operations and terminated a number of employees that had been employed before BSE discovery. Others held on to their cattle, not willing to sell at lower prices. Still others reduced their farm size because of uncertainties associated with BSE and turned to other sources of revenue such as grain farming or off-farm employment (Dunn, 2004). Bankruptcies as a result of losses increased in 2003. The bankruptcy cases in the primary sector of Canada in 2003 increased by 20.5% as compared to those in 2002, mainly due to sharp decreases in Canada's beef exports stemming from BSE (Office of the Superintendent of Bankruptcy Canada, 2006). Large-scale cow-calf operators in Canada may have suffered from BSE more than the small-scale operators. Serecon Management Consulting Inc. estimated that large-scale cow-calf producers in Canada had 19% income losses while small-scale cow-calf producers had 14% income losses due to the BSE discovery in 2003 (Dunn, 2004).

The occurrence of BSE has generated a number of uncertainties in the Canadian beef industry. One important issue is that cow/calf producers, feedlots and processors are not sure about how the discovery of BSE will affect exports, domestic demand in the future. Their expectations are partially based on past experience and current options available, which may suffer from the so-called "*bounded rationality*" problem. Namely, they are trying to be rational (maximize profits or utility) but "*neither their knowledge nor their powers of calculation allow them to achieve a high level of optimal adaptation of means to ends that is posited in economics*" (Simon et al., 1992, page 3).

Another important issue is the change in risk perceptions of producers and processors due to BSE events. Producers and processors make their decisions on their perceived risk, which may diverge from their objective risk. The perceived risk of BSE is subject to not only the decision-makers' previous experience[2], but also the information about BSE available from different sources (government,

[2] This previous experience may come from learning the result of foreign BSE cases or certain type of emergent risk happened before.

public media, industry, independent research institutes, etc.) and the trust of producers and processors in different information sources. This implies that the knowledge updating process of producers and processors on BSE risks may be quite complicated.

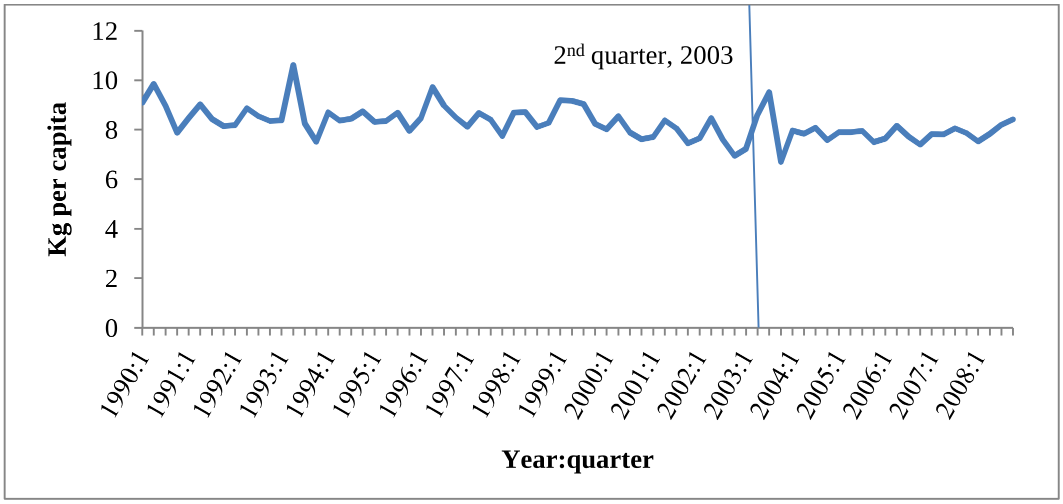
A third critical issue is the risk and length of BSE impacts on the Canadian beef industry. Because the shocks due to the BSE discovery in Canada came from both domestic and foreign cattle producers and beef consumers, a model of North American beef sector is required. Because the trade barriers imposed by trading partners were different and lifted at different times their individual impacts are uncertain. Additional issues include BSE-induced technical changes and government policy arrangements due to BSE.

1.2.2 BSE Impacts on Canadian Beef Consumers

Domestic demand, now that BSE has been discovered in the Alberta herd, may have higher uncertainty. The consumption of beef may decline or increase significantly in the long run as a result of BSE. In Great Britain, for example, the demand for beef and beef products decreased rapidly after the possible relationship between BSE and human vCJD was confirmed in 1996 but rebounded to the pre-1996 level in 3 years. However, the BSE cases in Canada seem to have had a different effect on meat consumption. Statistics Canada data showed that Canadians increased beef consumption on average in 2003 (Figure 1.4). Major reasons for this may be that the Canadian public showed their concern for BSE affected Canadian beef producers and raised their beef consumption (Statistics Canada, 2004b), and also that beef retail prices declined in the last half of the year 2003. Also, the fact that only one person has contracted vCJD in Canada[3] as compared to 129 people contracting vCJD in Great Britain (WHO, 2002) might have led to a lower risk perception of vCJD among Canadian consumers than that found among British consumers.

[3] The person who contracted vCJD actually was exposed to the disease in England.

Figure 1.4 Quarterly Beef Disappearance in Canada 1990-2008



Source: Statistics Canada beef disappearance data collected by Goddard.

Consumer behavioural changes can be driven by changes in prices or by changes in utility affected by risk perceptions, media coverage and advertising. BSE outbreaks and attendant media coverage can affect both prices and utility. The first issue is to rigorously determine whether or not the BSE discovery in 2003 had any effect on meat demand through affecting the relative meat prices. Normally, if beef prices decrease, the demand for beef will increase, as implied by conventional economic theory; it is not clear whether this effect may have swamped any negative influence from the risk perceptions associated with the BSE events. Related to price changes is an overall assessment of changes in meat expenditure and whether any changes are related to BSE. Although the quantity of beef consumption increased in the short run, beef's expenditure share in total meat expenditure has been decreasing continuously. Is the decrease in beef expenditure share related to foreign and domestic BSE risk? The second issue is how consumers construct their risk perceptions about BSE and how these risk perceptions affect their real purchasing behaviour. For consumers, their purchase decisions are, among other factors, based on how they perceive the risks they are exposed to, both qualitatively and quantitatively (Cox and Rich, 1964). It has been suggested that risk perception is based on social context, and that it is psychological factors underlying people's reactions to a certain risk rather than the objective or technical risk factors that affect behaviour (Frewer, 1999). From the psychology and sociology literature it is suggested that due to the media framing and description, imperfect risk communication, disbelief in government claims and personal cognitive limitations, perceived risk always diverges from objective risk by an amplification or attenuation process (Kasperson et al., 1988). A major hypothesis is that consumers make their risky decisions based on perceived risk instead of objective risk. However, the effects of risk perception on real purchasing behaviour are not clear yet. The third issue is whether media coverage of producers impacted by BSE discoveries in Canada did encourage Canadian beef consumption. This may, to some extent, reflect Canadian consumers' altruism or sympathy for BSE affected Canadian producers.

1.2.3 Canadian Media Coverage of BSE

The media can play a very important role in risk perception formation. From the British experience, the media framing and coverage of BSE contributed to people's perceptions about BSE risk (Verbeke et al., 1999a; Eldridge and Reilly, 2003; Finucane, 2002; Setbon et al., 2005). In Canada, the media attitude and magnitude of BSE issues varied over different time periods. In the very beginning of the 1990's, news articles about BSE in the Canadian media were infrequent and were centred on the BSE impacts in European countries. A possible relationship between BSE and human disease was also suggested. Only one news article out of *The Globe and Mail* addressed the fact that people might show symptoms of vCJD after a long time period (McLaren, 1990).

The media reports about BSE increased when the first case of BSE was discovered in Canada at the end of 1993. The blame was on an imported beef cow from England. In the media description, the government played a positive role in dealing with the BSE issues. The Canadian government was reported to be quick in reaction by killing several hundred cattle and tracing the contaminated animal (The Globe and Mail, 1994). It was not until 1996 that BSE became a major story in the Canadian media. In that year, many news articles focused on the proved relationship between BSE and human vCJD. The human vCJD was described as "*rare but incurable*", "*fatal*" (Papp, 1996). The beef fear was described as "*full flood*", beef was "*Killer steaks*" and "*worse than AIDS*". Further, it was suggested that vCJD might be transmitted through blood transfusion. The British consumers were reported to be "*scared*", "*not convinced*" and "*doubted*" about government policies (The Financial Post, 1996a; Winnipeg Free Press, 1996; The Globe and Mail, 1996a; 1996b). The British beef industry crashed from bans on British beef worldwide. On the other hand, Canadian beef was described as "*safe*" and Canadians were reported as not worrying about the beef sold in Canada (Laghi, 1996; Mahood, 1996; The Toronto Star, 1996). Canadian beef producers even hoped to "*fill*" the lack of beef supply in EU countries (The Financial Post, 1996b).

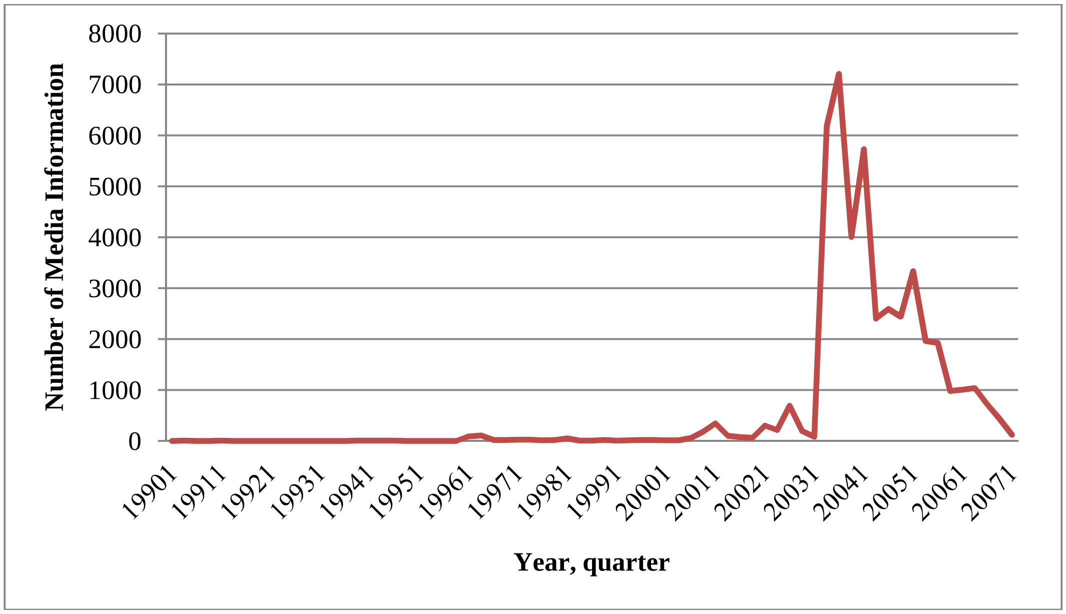
Before the first domestic case of BSE was found in Alberta cattle, the worry about human-prion disease (vCJD) caused much concern in the Canadian media. Most of the news articles focused on the first BSE-related death in Canada in August 2002 (Bernhardt, 2002; The Hamilton Spectator, 2002). The Saskatoon man whose death was related to the human form of mad cow disease may have gotten sick from eating contaminated meat in England (Bernhardt, 2002). The connection between mad cow disease and human vCJD was emphasized and the death of human vCJD patients in different countries reported (Woolhouse, 2002; Calgary Herald, 2002). The possible transmission of vCJD among people also drew large attention (The Globe and Mail, 2002; Broadcast News, 2002). However, the probability of transmission was suggested to be minimal (Lu, 2002; Peterborough Examiner, 2002; Prince Albert Daily Herald, 2002). Chronic wasting disease was also mentioned in news media as being related to BSE and possibly transmissible to human beings (National Post, 2002). Interestingly, some articles or TV news discussed the illogical or biased risk perception of BSE risk by meat consumers (Ford, 2002; Leader Post, 2002; CTV News - CTV Television, 2002). The government was portrayed by media as "*vigilant*" but there were also some opposite voices about the government in terms of delayed warning of the brain patch implants which might have put many people at risk of vCJD (Abraham, 2002). Researchers were described as "*not sure*" about the causes of BSE. They can't predict to what extent the human-type BSE infection would be found in the population (Kennedy, 2002). In spite of these apprehensions, the beef supply in Canada was suggested by the industry speakers to be safe and "*BSE-free*" (Buis, 2002; Foster, 2002).

The discovery of one domestic case of BSE altered the media's attitude to a great extent. The volume of news articles about BSE increased rapidly. There were 6179 articles from 140 Canadian newspapers, magazines and broadcast news about BSE and 'mad cow disease' in the second quarter of 2003, in contrast to 80 articles from 44 Canadian newspapers, magazines and broadcast news about BSE and mad cow disease in the first quarter of 2003. The media defined the BSE incidents with words such as "*Panic, scare, fear, worry, anxiety, not safe, dangerous, threat, disaster*". Around 460 news articles included these negative words in their titles in contradiction to 67 articles which included some positive words in the titles such as "*safe*" and "*confident*". Some of the media articles illustrated the perception that Canadian consumers were worried about the BSE discovery and might decrease beef consumption in the future (Canada NewsWires, 2003). Others suggested that most Canadians would remain loyal to Canadian beef (Cape Breton Post, 2003; Chatham Daily News, 2003) and would rally to the support of BSE affected beef producers by raising their beef consumption (Broadcast News, 2003). The media reported that the BSE impacts on the industry were disastrous. Almost all the news messages mentioned the border closures due to the domestic BSE case, noting the link to big losses in the Canadian beef industry and for beef producers. The BSE impacts on producers were depicted as "*Bombshell*" and "*hard blow*" for Canadian producers (Morrison, 2003; Canada AM, 2003). Government, on the other side, was criticized for its slow reaction to both 'mad cow disease' testing and the border closures from other countries including U.S. (The Canadian Press, 2003; The Hamilton Spectator, 2003). In the meantime, SARS was frequently cited with BSE[4] in major stories because they happened almost simultaneously and because both resulted in big losses in the Canadian economy (The Toronto Star, 2003). This framing of BSE stories may have intensified consumers' perceptions about BSE risk or called up their attention to producers' economic losses, encouraging them to eat more beef.

[4] There are 33 articles with headlines including both "Mad cow disease" and "SARS" .

In the years after 2003, Canadian media coverage of ‘mad cow disease’ increased around the time periods where BSE cases were discovered. However, the magnitude of Canadian media involvement on BSE issues gradually declined. The gross media coverage of BSE is illustrated by Figure 1.5.

Figure 1.5 Quarterly Media Coverage of BSE in Canada 1990 to 2007



Source: The articles are collected from Factiva, CBCA Business, CBCA Current Events, CBCA Reference, ProQuest Newspapers (see Appendix A).

Most newspapers and broadcast news put a focus on international trade in Canadian beef products and live cattle, especially with U.S. Apparently, the new cases of BSE-contaminated cows after the case in May, 2003 had negative impacts on the reopening of borders from other countries (Kamloops Daily News, 2006). As the media suggested, the government played a very positive role in the efforts to reopen the border to U.S. beef and cattle markets and to help the BSE affected producers. However, the federal government was strongly blamed for “*gross incompetence*” and “*negligence*” in tracking imported cows (The Globe and Mail, 2005; Canada NewsWire, 2005). For Canadian producers, there was big uncertainty about when the U.S. would reopen its border to trade in live cattle. The producers were depicted as “*fighting for survival*”,” *badly in debt*”(The Globe and Mail, 2004; Edmonton Journal, 2006). As reported by The Canadian Press (2004), Canadian producers were exhausted from financial losses, insufficient government aid and the border shutdown from other countries to Canadian beef.

On the consumer side, consumer groups were critical of the low level of BSE testing, the lack of fairness in paying higher prices for beef thus rendering the beef processor more profitable, partially due to ill-designed government subsidy policies (Kopala, 2004; CanWest News, 2004; Abbotsford Times, 2004). Certain survey reports based on Decima-Investors Group Index revealed that Canadian consumer confidence about current and future economic conditions declined across Canada at the end of first quarter of 2004 possibly partially due to the 'mad cow disease' problem (Canadian Press NewsWire, 2004). In some of the media reports, Canadian consumers showed sympathy for Canadian producers who were hit strongly by BSE related border closures. The most frequently used word in describing consumer support for Canadian beef producers is "*rally*". Canadian consumers were often depicted as loyal to Canadian beef and supportive of Canadian beef producers.

As has been long established in psychology and sociology, risk perceptions are affected by both quantity and quality aspects (attitudes, story framing, addressed subjects in the stories) of media coverage. Economic researchers have examined the impacts from a quantity aspect and from an attitude aspect. However, there are few studies focusing on the quality aspects such as story framing, with the exceptions of Frewer et al. (1993), Gaskell (2000), Marks and Kalaitzandonakes (2001). The lack of studies may be because the framing effects are hard to track and incorporate into an economic model. Another shortfall of current economic studies on risk perception is the lack of research on the evolution of risk perceptions, which are shaped by media information and have a big influence on consumer decision-making. The difficulty may come from the availability of consumer risk perception data over time. Usually, risk perceptions are measured through designed experiments, which are one-shot games and not measured over time. However, if risk perceptions are continuously updating over time, the experimental approach may not be sufficient. The third inadequacy of risk perception studies is that the effects of media coverage of BSE on producers' risk perceptions have not been addressed yet according to a search for relevant documents in existing literature.

1.3 Study Objectives

Diseases, such as BSE, can affect human and animal health and revenues in beef and other related industries. It is unforeseeable whether more disease outbreaks will occur and a problem remains as to how public policy should react to these outbreaks appropriately. The reactions by legislators require knowledge of the severity of the risks associated with the diseases and the long term adjustments of producers and consumers. Also, it should be noted that BSE is not just a Canadian issue but a issue for North America and rest of world given the integration of the North American beef and live cattle markets (Caswell and Sparling, 2005). The outbreak of BSE in Canada may also have affected the beef sector in the U.S. and vice versa. Given these issues, this thesis has the following objectives:

1. Construct and estimate a consumer demand model to examine the BSE impacts, study the evolution of risk perceptions about BSE and quantify the effect of media coverage on BSE risk perceptions of beef consumers in Canada. Structural breaks due to BSE will also be tested for in the consumer demand models by both parametric and non-parametric approaches. From a consumers' perspective, BSE risk perceptions may be reflected in the changes in meat purchasing behaviour and may not be stable over time. The effects of the quantity and quality of media coverage about BSE may have led to an evolution of consumers' risk perceptions. There are many studies about the impact of media coverage on risk perceptions. However, these studies did not specify the dynamic adjustments in risk perceptions in a sufficient way and therefore, may be incomplete. In order to track consumers' risk perception changes through consumer demand models, it is necessary to disentangle the impacts of other demand shifters on meat consumption such as prices, income, habit formation, seasonality, time trend and demographic profiles of different consumers. Further, different types of datasets may provide more robust results for consumer behaviour. Given these considerations, the consumer demand models in this study will incorporate both BSE risk perceptions and factors other than BSE and will be analyzed by both time series data and panel data.

2. Construct and estimate a cow-calf producer model (including beef cow inventory equations and slaughter cow supply equations) to examine the BSE impacts, study the evolution of producers' risk perceptions about BSE and quantify the effects of media coverage on BSE risk perceptions of cow-calf producers in Canada. Structural breaks due to BSE will also be tested for based on the cow-calf producer model. From a producers' perspective, BSE risk perceptions may be reflected in the behavioural changes of cow-calf producers and may not be stable under the impacts of different BSE information. The effects of BSE media coverage on cow-calf producers' risk perceptions have not been analyzed yet in the existing literature. In order to track producers' risk perception changes through producers' supply models, we may also need to disentangle the impacts of other cattle supply shifters such as input and output prices, seasonality, time trend for structural changes, government programs and regional differences. Further, time series data for different regions may provide more robust results for cow-calf producers' behaviour. Therefore, the cow-calf producer models will incorporate both BSE risk perceptions and the factors other than BSE and will be evaluated by regional time series data.

3. Develop a beef sector model to evaluate the BSE impacts on the beef and live cattle industry in Canada. The discovery of BSE led to border closures from other countries to beef and live cattle, imposing a big shock on the Canadian beef and cattle industry. The BSE risk perceptions of beef consumers and producers in Canada may have created additional shocks for the beef sector equilibrium. It is not clear what the mixed effects of the two types of shocks are. These impacts need to be estimated and simulated empirically.

1.4 Conceptual, Empirical and Policy Contributions

Conceptually, a framework called the Social Amplification of Risk Framework (SARF) derived from sociology, psychology and economics and the Prospective Reference Theory (PRT) could be applied in the economic analysis of consumer and farmer behaviour to track the dynamics of their risk perception changes. The application of SARF and PRT in economic analysis is a unique contribution of this thesis.

Empirically, rather than the frequently-used stated preference approach to eliciting people's risk perceptions, two approaches based on revealed preference data are suggested to elicit people's risk perceptions: a predictive difference approach and a state-space approach. In the predictive difference approach, people's risk perceptions are approximated through the differences in predictions based on data before a certain risk event and predictions based on data including the certain risk event. This approach has been seen in the existing literature of risk analysis (van Ravenswaay and Hoehn, 1991; Liu et al., 1998). In the state-space approach, people's risk preference parameters and behavioural response (demand or supply) parameters are estimated jointly through either linear or nonlinear state-space models based on time series data and panel data for consumers and producers. The state-space model will be estimated through Bayesian methods via Gibbs sampling. The estimation of risk perceptions through state-space models and Bayesian methods makes an empirical contribution to the existing literature of agricultural economics[5].

Another unique approach in this study is the parametric and non-parametric structural break tests for BSE impacts on consumer and farmer behaviour. While the parametric and non-parametric structural break tests for BSE impacts are seen in the existing literature, the approach developed in this study represents an advance over previous work. In terms of parametric methods, a generalized predictive test (Dufour et al., 1994) is applied, a first effort to test the structural break over a nonlinear meat demand system when there are insufficient observations after the possible break point for model estimation. The generalized predictive test can be also applied to the producer supply equations under the similar situations. In terms of non-parametric methods, the non-parametric rank

[5] Mazzocchi (2006) applied state-space model to an Almost Ideal Demand System. However, he did not specify the risk perception formation. McCluskey and Rausser (2001) specify a hedonic price model in which the risk perceptions in the hazardous waste site are incorporated and allowed to evolve over time through a Bayesian updating process given contemporary media information. However, their models don't include a demand equation or demand system and they applied a Generalized Maximum Entropy approach to estimate it.

tests such as Friedman and Kendall tests are applied for household panel data of consumers[6], which also adds to the existing literature.

The policy contributions of this thesis are identified as follows. First, the consumer and producer models can provide the basis for "what if" analysis, simulating the reactions of consumers and producers to BSE issues and providing good instruments for the government to use in the design of traceability, insurance and food safety policies. The models can be used by government to predict the impacts of other similar risks on agricultural production and consumer demand in the future. Second, the government can get more quantitative information about the impacts of export shocks due to BSE and design better policy arrangements for negotiating international trade. Prior to May 2003, the Canadian government had no issues with the OIE recommendation of banning trade for seven years with countries that have BSE occurrence. Their views changed considerably after May 2003. Third, the government can get a better understanding about how the media can impact risk perceptions of BSE and other zoonotic diseases by consumers and producers and develop better strategies to enhance risk communication. Fourth, a clear idea about the changes in beef consumers' and producers' risk perceptions about BSE could be very beneficial for industry. The beef and cattle industry can have more information about the beef demands of consumers and the supply responses of its members and improve industry policy and marketing decisions accordingly.

1.5 Thesis Overview

A comprehensive review of the theory and evaluation of risk perceptions, beef sector studies, and BSE impacts on the beef sector is presented in Chapter 2. Bayesian econometric methods are also reviewed in Chapter 2 to provide guidance for model estimation. In the section on risk perception theory, risk

[6] The non-parametric tests can also be applied to cow-calf producers' decision-making if the data of all inputs and outputs and associated prices are available. However, the farmer level panel data are not readily available and some input data may be hard to obtain or estimate. Further, technical changes may also play certain roles in structural breaks of farmers' behaviour and make it difficult to separate the structural breaks due to BSE outbreak from the technical change. Given these considerations, the non-parametric structural break tests are not employed for the farm-level model.

perceptions, and the evolution of risk are reviewed from economic, sociological and psychological aspects with an emphasis on the SARF. The existing literature on the measurement of risk perceptions of consumers and producers is also summarized, providing both theoretical and empirical support for the evaluation of risk perceptions about BSE. Beef sector structure and performance are reviewed in terms of beef and cattle production, supply and marketing. The studies about BSE impacts on meat demand and beef, cattle production and marketing are also reviewed. This literature review provides a basis for the model construction for consumers' and producers' behaviour.

In Chapter 3, the empirical models for consumers and cow-calf producers are developed and the predictive difference approach and the state-space approach are applied to track risk perceptions about BSE over time. Models based on time series data and panel data are specified and the methods for evaluating the effects of non-BSE factors are discussed. Further, parametric and non-parametric structural break tests are explored. These model specifications and statistical tests provide empirical guidance for the estimations of consumer and cow-calf producer models.

In Chapter 4, Canadian consumers' behaviour under the impacts of BSE is analyzed. Different consumer media indices about BSE in Canada are constructed to reflect both the quantitative and qualitative aspects of BSE information available to Canadian consumers. A risk perception equation for BSE for Canadian consumers is developed based on various BSE media indices, and based on the methods derived from SARF and PRT. The risk perception equation is then evaluated through both a predictive difference approach and a state-space approach. Specifically, in a predictive difference approach, the risk perception of BSE[7] is approximated by the difference of predictions of beef expenditure shares from a demand model based on the data before BSE outbreak and a demand model based on the data including BSE outbreak. The risk perception of BSE is then used as a dependent variable in the risk perception equation to evaluate the

[7] The risk perception of BSE evaluated by predictive difference approach is actually a deviation of risk perception after BSE outbreak from the baseline risk perception before BSE outbreak.

impacts of various media indices of BSE in risk perceptions of BSE. In a state-space approach, the risk perception equation of BSE is incorporated into the demand model and the parameters in the risk perception equation and the demand model are estimated jointly through Bayesian methods. In both of the approaches, the significance of the parameters in the risk perception equation is examined for the empirical evidence of SARF and PRT. Also, the parameters of media indices of BSE affected Canadian producers due to the BSE outbreak can indicate whether Canadian consumers are sympathetic or altruistic toward the BSE affected Canadian producers. Further, structural breaks in consumer preferences are tested by both parametric and non-parametric approaches for the period when the first North-American BSE-infected cow was found in May, 2003, the period when an imported cow from U.K. was found infected by BSE in the end of 1993, the period when the possible relationship of BSE and human vCJD was announced by U.K. government in January, 1996[8] and several periods when many cases of cows were found infected by BSE after 2003. These structural break tests provide the evidence about whether Canadian consumers have changed their preferences due to foreign and domestic BSE risk. The demand elasticities and risk perception elasticities are also evaluated and compared across different consumer groups and different time periods.

In Chapter 5, the behaviour of Canadian cow-calf producers under BSE impacts is evaluated. The empirical model applied for cow-calf producers' behaviour is mainly derived from the work of Jarvis (1974) with a hypothesis of adaptive expectation. Two equations are estimated including beef cow inventory equation and slaughter cow/bull supply equation. The risk perception equation for BSE held by Canadian cow-calf producers is constructed in a similar way as that for Canadian consumers. Various media indices of BSE are incorporated into the risk perception equation to reflect both the quantity and quality of media information about BSE available to Canadian cow-calf producers. The producers' risk perception about BSE is evaluated by a predictive difference approach and a state-

[8] The structural break tests before for 1991 and 1996 can only be done for the time series data because the panel data of Canadian consumers we have only start from 2002.

space approach. In a predictive difference approach, the risk perception of BSE[9] is approximated by the difference of predictions of slaughter cow/bull supply from a slaughter cow/bull supply model based on the data before BSE outbreak and a slaughter cow/bull supply model based on the data including BSE outbreak. The risk perception of BSE is then used as a dependent variable in the producers' risk perception equation to evaluate the impacts of various media indices of BSE in producers' risk perceptions of BSE. In a state-space approach, producers' risk perception equation of BSE is incorporated into the slaughter cow/bull supply model and the parameters in the risk perception equation and the slaughter cow/bull supply model are estimated jointly through Bayesian methods. In both of the approaches, the significance of parameters in the producers' risk perception equation is examined for the empirical evidence of SARF and PRT. The structural break tests for cow-calf producers' behaviour are also employed in the same time periods as that of consumers to track the impacts of domestic and foreign BSE outbreaks.

In Chapter 6, a synthetic model of the Canadian beef sector will be constructed and used for simulations of the impacts of BSE risk perceptions of consumers and cow-calf producers as well as the impacts of BSE-related border closure. The synthetic model will also provide predictions about the impacts of a possible disease outbreak in the future and provide the basis for policy recommendations for government.

In Chapter 7, a summary of the empirical analyses of consumer and producer behaviour will be provided. The results for each objective will be discussed. The policy implications derived from this study will be summarized. The approaches to approximating risk perceptions through market behaviour including the predictive difference approach and the state-space approach will be discussed in terms of their limitations. Some extensions of this thesis will also be explored.

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[9] Similar to that of consumers, the risk perception of BSE of cow-calf producers evaluated by predictive difference approach is actually a deviation of risk perception after BSE outbreak from the baseline risk perception before BSE outbreak.

Chapter 2 Literature Review

2.1 Introduction

The research about the economic impacts of BSE on beef consumers and cattle producers' behaviour involves risk perception theory and beef sector models. In order to construct a comprehensive framework for the analysis of BSE's impacts, a review of risk perception theory and beef sector models is required and will be undertaken in the following sections. Current studies of BSE impacts on consumers' and producers' behaviour are included in the review and discussion. At the end of this chapter, a summary highlighting the implications for the current research is provided.

2.2 Theory of Risk Perception

The connection between BSE and vCJD has been confirmed and vCJD has been found to be linked to the consumption of beef from BSE-contaminated cattle (Public Health Agency of Canada, 2007). Since the link exists, Canadian consumers may have felt consumption of beef and beef products to be more risky after BSE-infected cows were found in Canada as compared to the time period before BSE-infected cows were identified. At the same time, producers have faced bigger risks (particularly financial) in cattle production after BSE-infected cows were identified as compared to before, particularly because of the economic outcome of trade barriers. In order to analyze changes in perceived risks (health and financial) held by people, it is necessary to review the related literature about people's choices under uncertainty and risk and risk perception theory.

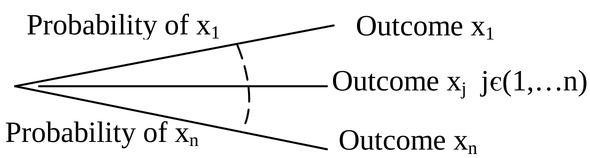
2.2.1 Choice under Uncertainty and Expected Utility Theory

People make their decisions under uncertain or risky outcomes[10]. For example, producers may need to make production decisions under an uncertain economic environment. Consumers may need to make food intake decisions without

[10] Risk and uncertainty are used interchangeably in this thesis because it may be difficult to differentiate them. However, Knight (1921) discussed the definitions of risk and uncertainty and the difference between them. Specifically, risk is a situation where all the outcomes and the related probabilities can be found. In contrast, uncertainty is a situation where not all the probabilities of outcomes are known.

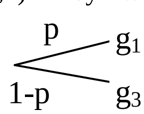
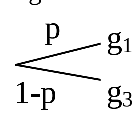
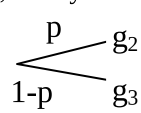
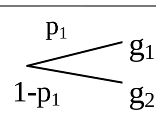
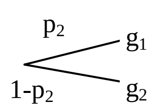
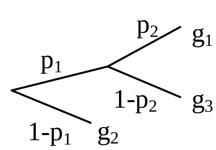
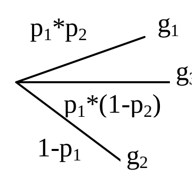
knowing the human health implications. The set of uncertain or risky outcomes may be described by means of objectively known probabilities. The probability expressions of all possible outcomes are defined as lotteries (Mas-Colell et al., 1995). A lottery can be expressed as:

Figure 2.1 Illustration of A Lottery



where x's are the outcomes. If the decision maker's preferences over lotteries satisfy certain axioms such as completeness and transitivity, betweenness (or certainty equivalent), independence, monotonicity and reducibility[11] (Shoemaker, 1982), his or her preference can be represented by a utility function with the expected utility form. Assuming m lotteries K_i(i=1,..m) over n possible outcome g_j (j=1,..n) with probabilities p_j (j=1,..n), these axioms can be represented by the information in Table 2.1.

Table 2.1 The Axioms of Expected Utility Theory

<table>
<tr><th>Completeness</th><th>Transitivity</th><th>Betweeness</th><th>Independence</th></tr>
<tr><td>K_1 is at least as good as K_2 or K_2 is at least as good as K_1</td><td>K_1 is at least as good as K_2 and K_2 is at least as good as K_3 implies K_1 is at least as good as K_3</td><td>For three outcomes g_1 g_2 g_3, If $g_2 \in (g_1,g_3)$, we can always find a probability $p \in (0,1)$ by which lottery  is the same attractiveness with g_2.</td><td>If g_1 and g_2 are regarded the same by people, lottery  and lottery  are also the same for people.</td></tr>
<tr><th colspan="2">Monotonicity</th><th colspan="2">Reducibility</th></tr>
<tr><td colspan="2">For lottery K_1 =  and lottery K_2= , if g_1 is strictly preferred than g_2, then K_1 is strictly preferred to K_2 if and only if $p_1>p_2$.</td><td colspan="2">A compound lottery (i.e. one whose outcomes are themselves lotteries) is regarded the same as the simple lottery where the probabilities are multiplied through the standard probability theory. For example, lottery  is regarded the same as: </td></tr>
</table>

[11] These properties were not given explicit names in Shoemaker's paper but they are named here for simplicity.

Given these axioms, a utility function U over the expected outcome can be represented as (Mas-Colell et al., 1995):

$$U(\sum_{i=1}^{I} p_i K_i) = \sum_{i=1}^{I} p_i U(K_i) \ , \tag{2.1}$$

where K_i is the i^{th} lottery and probabilities $(p_1,\ldots p_i)\geq 0$, $\sum_k p_k=1$. If we define the lottery K_i with only one certain outcome g_i, the expected utility over I outcomes is:

$$U(\sum_{i=1}^{I} p_i g_i) = \sum_{i=1}^{I} p_i U(g_i) \tag{2.2}$$

An expected utility function U(.) is defined on the lotteries, in contrast to the utility function u(.) defined over a definite outcome. To differentiate them, U(.) is called the von-Neumann-Morgenstern (v.N-M) utility function (von Neumann and Morgenstern, 1947) and u(.) the Bernoulli utility function (Bernoulli, 1954).

Decision makers usually differ in their risk attitudes (Burkett, 2008, p219). A decision maker is risk-averse if he/she prefers a certain outcome to a gamble with indefinite outcomes (e.g. 50% chance of winning 100$ and 50% chance of losing 100$). If the decision maker prefers the gamble to the certain outcome, he/she is a risk-seeker. If the decision maker is indifferent between the gamble and the certain outcome, he/she is risk-neutral. The risk attitude may be reflected by the shape of Bernoulli utility function u(.) (Mas-Colell et al., 1995). If u(.) is a concave function, the expected utility of outcomes is no more than the utility of the expected outcome and the decision maker is risk-averse. It is possible that the expected utility of outcomes is equal to the utility of the expected outcome for a risk-averse decision maker. If u(.) is strictly concave, the decision maker is strictly risk-averse and the expected utility of outcomes is always less than the utility of the expected outcome. Similarly, if u(.) is a strictly convex, the decision maker is strictly a risk-seeker.

Another related concept is certainty equivalent, which is defined as the amount of money providing the decision-maker with the same utility as the lottery K(.). The decision-maker is risk-averse if the utility of the certain equivalent is no more than the expected utility of the lottery K(.) (Mas-Colell et al., 1995). The risk attitudes such as risk-averse, risk-neutral or risk-seeking can be used to classify decision-makers into different groups. In order to compare and measure people's risk attitudes, the Arrow-Pratt Absolute Risk Aversion (APARA) and the Arrow-Pratt Relative Risk Aversion (APRRA) functions have been proposed (Arrow, 1965; Pratt, 1964). With a Bernoulli utility function u(.) over a monetary outcome g, APARA and APRRA are defined as:

$$APARA=-u''(g)/u'(g) \quad \text{and} \quad APRRA=-g*u''(g)/u'(g) \tag{2.3}$$

Assuming person 1 and person 2 have concave Bernoulli utility functions u_1 and u_2 respectively, with the definition of APARA, the statements in the following table are equivalent.

Table 2.2 The Comparisons of Risk Levels across Individuals

Person 1 is more risk averse than person 2	APARA1 ≥APARA2	There existing an increasing concave function f(.) such that u1(g)=f(u2(g)). In other words, u1(.) is more concave than u2(.)	Certainty equivalent of person 1 ≤ Certainty equivalent of person 2 for any K(.)	Any risk that person 1 will accept will also be accepted by person 2.

One criticism of expected utility is the objective nature of the probabilities. The assumption that the probability is regarded as an objective fact by a decision maker is rarely true in reality. People may make judgements about the chances of uncertain events based on their pre-held probabilistic beliefs or subjective probabilities (Shoemaker, 1982). This leads to many studies about how people perceive the risk they face such as subjective expected utility theory. Different people may face different types of risk and may have different risk perceptions. For example, consumers may face risks from food borne diseases and producers may face risks from product prices. Consumers may have different risk perceptions over food borne diseases as compared to producers. In the following sections, the literature about risk perceptions, risk perception evolution and empirical measurements of risk perceptions will be reviewed.

2.2.2 Risk Perception

Individuals may perceive risks differently from objective risk. This involves a lengthy discussion about the measurement of risk. In professional risk assessment, risk is reflected by the objective probabilities from scientific and engineering estimates and their associated outcomes. In reality, people cannot get all the required information about the risky events or even understand them. They also have difficulty discriminating among the large amount of information about risks and making their optimal choices in the real world. They are actually suffering so-called '*bounded rationality*" and are incapable of behaving like the rational beings portrayed in standard rational choice models (Simon et al., 1992). When individuals confront a puzzle (for example, a risky choice), they usually look for some related issues and messages, and quit when their conceptions about the puzzle reach to a certain level. Individual's conclusions are often not the same and may even not be true in the real world (Frank, 2003). This problem of bounded rationality creates other research issues. One hypothesis is prospect theory under which people are assumed to be making their decisions based on how prospects are perceived, where a prospect is a possible outcome with an associated probability. Generally, people may care too much about low probability outcomes and underestimate high probability outcomes (Kahneman and Tversky, 1979).

In fact, the individuals' risk perceptions are subject to many factors including psychological and sociological aspects. It is these factors that guide people's responses to certain risky issues instead of the scientific or technical risk estimates (Frewer et al., 2002). Different types of risk also lead to various reactions. For example, risks from voluntary behaviour are not the same for people as risks from involuntary behaviour and newly-emerged risks are different from familiar risks (Finucane, 2000).

There are two competing theories aimed at explaining risk perceptions. One is the psychometric paradigm (Kahneman and Tversky, 1979; Kahneman et al., 1982; Slovic, 2000) and the other is culture theory (Thompson and Wildavsky, 1990). In the psychometric paradigm, people construct their perceptions over certain risky issues not only based on objective risk but also based on psychological effects such as anchoring, availability, representativeness, etc. In culture theory, people build their risk perceptions relative to their own cultures. The theory of risk perceptions most closely related to economic studies is the psychometric paradigm. Culture theory is mostly applied in anthropology and sociology contexts.

In the psychometric paradigm, heuristics and judgment bias are often cited as important factors affecting risk perceptions. Tversky and Kahneman (1974) discussed three heuristics: representativeness, availability and anchoring. Representativeness is defined as the probability that A is similar to and can represent B. Availability is the determination of the probability of an event by the recalled number of relative events which have occurred previously or by the images of the event existing in mind. Anchoring is making the judgements over probabilities with some thresholds or anchors based on certain information. These anchors or thresholds are then updated given additional information (Slovic et al., 2000a, 2000b). Of the three heuristics, availability is often cited as important for understanding risk perception (Tversky and Kahneman, 1973). Mass media coverage of certain risky events may enhance the memory of people about the risky event and the availability bias, leading to a high level of perceived risk (Combs and Slovic, 1979).

Individuals' risk perceptions are not only affected by the amount of information but also the attitude and the source of information (Frewer et al., 2002). The media may have either positive or negative attitudes toward certain risky issues. Negative news may lead to a decrease in consumption or vice versa. Criticism or credit may be given to certain agents such as government, industry or independent research institutes. Meanwhile, the opinions about food risk from government, industry, independent research institutes, consumer groups and journalists themselves can also be transmitted through media. The extent to which an individual perceives risk is linked to the individual's trust in these different information sources. The relationship between risk perception and trust has been investigated in media and information studies (Slovic et al., 1991; Frewer et al., 1996). Trust plays a very important role in risk perception formation and is connected to risk communication (Petts and Leach, 2000; Spangler, 1984; Siegrist and Cvetovich, 2000).

Trust can be characterized with several dimensions. The first dimension concerns how people perceive that the institutions or individuals make their decisions in an unbiased and fair way and provide accurate good information. The second dimension concerns how people believe that the institutions or individuals are competent in their work. The third dimension concerns how people perceive that the responsible institutions or individuals care about people's benefits. The fourth dimension concerns how people perceive that the responsible institutions or individuals realize their expectations (Kasperson et al.,1992). People may pay more attention to the ability of government to control risk instead of removing it completely (Starr and Whipple, 1984). Trust is also seen to be fragile because it is hard to build but easy to break down, which creates certain problems in risk communication and management (Botterill and Mazur, 2004). Under some circumstances, people are so suspicious of the announcements from certain social organizations that the risk communication from these organizations is counter-effective and harmful (Slovic, 1993; Fox and Irwin, 1998; Brandow, 1966). The British public's response to the BSE crisis is an illustration of a loss of trust in the government (Langford, 2002).

Other psychological factors affecting risk perceptions include perceived locus of control, perceived outrage or dread associated with the risk. Perceived locus of control represents to what extent people believe they can deal with certain risks (Grobe et al., 1999; Nganje et al., 2005). Perceived outrage or dread of the risk represents to what extent people feel the risk is serious, which is associated with factors such as voluntariness, controllability, lethality and fairness (Sandman, 1989).

Apart from these psychological factors that affect people's risk perceptions, as implied by culture theory, social and cultural characteristics also play important roles in risk perception determination. Social and cultural factors including age, gender, and place of residence, as well as economic factors such as income level may have an impact on people's risk perceptions (Adu-Nyako and Thompson, 1999).

2.2.3 Evolution of Risk Perception

Risk perception may not be constant over time. It can be affected by media coverage, demographic and psychological factors (Kasperson and Kasperson, 2005a). The changes in volume of information on certain food risks in each time period may be correlated with risk perceptions. No economic theories have addressed risk perception evolution in a sufficient way. In contrast, a sociological framework called the Social Amplification of Risk Framework (SARF) (Kasperson et al., 1988) developed in the late 1980's, has contributed to help explain the evolution of risk perceptions.

The SARF can be used to describe the multiple facets of risk problems and the dynamic processes of risk perceptions and responses. Particularly, people may construct their risk perceptions very differently than the experts' views. When the risk or risk event is described by various risk signals such as images, signs and symbols, these signals interact with people's psychological, social, institutional, or cultural characteristics and this may result in either the amplification or attenuation of the risk (Pidgeon et al., 2003).

The roots of SARF lie in direct personal experience and in indirect, or secondary, experience obtained through the use of information related to the risky events. People exposed to the risk in person will have a higher risk perception as compared to people never exposed to the risk (Slovic, 1987a). However, direct experience can also provide messages about the characteristics of the hazard, accelerating research and enhancing the ability to decrease risks. Therefore, direct personal experience may play both negative and positive roles at the same time. When people haven't experienced the risk, they may rely on various information sources such as personal communication and the media. Information flow plays an important role in shaping public response and acts as an amplifier of risk. Attributes of information that may influence the SARF include volume and framing effects (Slovic, 1987b). Without considering the content of information, risk perceptions may have a strong positive correlation with the number of messages about the risk. The high number of risk messages about certain technical hazards may also invoke associations with the related risky events which have occurred previously, the attribution of failure to government policies and a rise in risk perceptions. Therefore, as compared to natural risks, technical risks may be more destructive (Kahneman et al., 1982).

As discussed above, people get their risk information through the news media and informal interpersonal communications. Media play a crucial role in information channels. Media may be biased in reporting the risks with rarely-occurring risks taking more weight than common risks. Due to the possibly biased reports from media, it is not surprising that people have biased estimates about different causes of death (Combs and Slovic, 1979, in Kasperson and Kasperson, 2005b).

Public trust in institutions has been recognized as being an important part of the SARF. Credibility (expertise) of information sources is one important component of trust which affects the impacts of information about risk (Petty and Cacioppo, 1984; Renn and Levine, 1991; Frewer, 2003; Priester and Petty, 1995). If people feel an information source is more reliable than other information sources, they will put a higher weight on the information obtained from such an information source. Therefore, information about certain risks from more reliable information sources may raise people’s risk perceptions as compared to that from other sources. The information from the media can also be classified in terms of different sources and may impose different impacts on risk perceptions (Frewer, 2003; Frewer et al., 1998; 1999). As two important information sources, local media and national or international media may also have different impacts on risk perceptions due to their different focuses. Local media may focus on reporting risky issues from local economic perspectives. The national and international media may focus on national or international risk management. Also, radio or television media may not have the same impacts on risk perceptions as printed media (Frewer et al., 1998; 1999; Chaiken and Eagly, 1983).

Pidgeon et al. (2003, page 13-16) argue there are two stages in the SARF. In the first stage of the SARF, the signals of risk and risk events are interacting with many psychological, social, institutional or cultural factors and are either amplified or attenuated by various *“social and individual amplification stations”*.

Amplification stations can include individuals, social groups, and institutions, for example, scientists or scientific institutions, reporters and the mass media, politicians and government agencies, or other social groups and their members.

For *"social stations of amplification"*, the character of institutions such as institutions' objectives and institutional culture influence signals trust (Pidgeon et al., 2003 page 13). Individuals from different institutions may construct their risk perceptions based on the values of their institutions (Johnson and Covello, 1987; Slovic, 1987b).

"Individual stations of amplification" are affected largely by psychology factors such as heuristics, characteristics of risks, prior beliefs and trust (Pidgeon et al., 2003, page 16). Demographics also play an important role in individual stations of amplification (Trumbo, 1996).

In a second stage of the framework, the risk event may generate *"ripples"* of secondary consequences that may spread far beyond the initial impact and eventually affect other related technologies or institutions. Such secondary impacts include market effect (consumer avoidance), industry effect, demand for regulation constraints, loss of creditability and trust, etc. (Pidgeon et al., 2003, page 16).

2.2.4 Empirical Measurement of Risk Perceptions

There are different approaches to evaluate individual risk perceptions. In terms of consumers and producers, the studies of risk perception measurement are summarized in Table 2.3 and 2.4.

Table 2.3 The Empirical Studies of Consumer Risk Perception Measurement

Empirical Studies	Models
van Ravenswaay and Hoehn (1991), Liu et al. (1998), Zepeda et al.(2003)	Demand model with the risk perception approximated by the demand changes after occurrence of food risk; Demand model with risk perception incorporated from a designed survey.
Frewer et al. (1993), Williams and Hammitt (2001), Frewer et al.(2002) ,Frewer et al. (2003), Nelson (2004) , Schroeder et al.(2007)	ANOVA, MANOVA analysis, factor analysis, principal component analysis or structural equation with designed consumer surveys based on psychometric paradigm.
Timothy,et al.(1992), Hammitt (1990), Pennings et al. (2002), McCluskey et al. (2005), Moon et al. (2007), Elsa et al.(2007), Akgungor et al.(2007), Tonsor (2007), Veeman and Li (2007)	Discrete choice model with data collected from designed consumer surveys based on psychometric paradigm.

Weber et al.(1997), Verbeke et al. (1999a), Gaskell (2000), Lima (2004), Hallman et al. (2004), Setbon et al. (2005)	Descriptive analysis with designed experiments or surveys
Hayes et al. (1995)	Experimental auction model with statistical tests
Eom (1995)	Theoretical model with risk perception constructed as an index of averting expenditure and food safety information
Frewer et al. (1997)	Optimistic bias, procrustes analysis, correspondence analysis, preference mapping by statistical analysis including analysis of variance , mean comparison
Frewer et al. (1997)	Elaboration likelihood model based on the survey responses by statistical analysis including experiment design and analysis of variance
Kalaitzandonakes and Marks (1999)	Content analysis model with risk perceptions elicited from designed questions with certain statistical analysis
Alvensleben (2002)	Picture stimuli with certain descriptive analysis
Harrison et al.(2007)	Lottery experiments with designed survey

Table 2.4 The Empirical Studies about Producer Risk Perception Measurement

Empirical Studies	Models or estimation methods
Quiggin (1981), Gunjal and Legault (1994), Pennings and Smidts (2000), Pennings and Garcia (2001), Bard and Barry (2001), Liu (2008)	Expected utility or non-expected utility model with risk perceptions and attitudes constructed with the lottery experiment data.
Young and Shumway (1991), Wilson et al.(1993), Popp et al. (1998), Popp et al. (1999), Isengildina and Darren (2001), Nganje et al. (2005), Bitsch and Olynk (2007)	Discrete choice model with risk perceptions constructed through survey responses
Bard and Barry (2000), Pennings and Smidts (2000), Meuwissen et al. (2001), Akcaoz and Ozkan (2005), Maybery et al. (2005), Fausti and Gillespie (2006), Nicol et al. (2007), Stordal et al. (2007), Toma and Mathijs (2007), Greiner et al. (2008)	Based on psychological paradigm, comparing different scales for farmers' attitudes or different responses from the survey by statistical methods such as convergence validity, reliability test, factor analysis and structural equation approach.
Knutson et al.(1998), Rimal and Schmitz (1999), Hall et al. (2003), Pinochet-Château et al. (2005), Flaten et al.(2005), Xu et al.(2005), Thorsten et al. (2006), Fausti and Gillespie (2006), Medina et al. (2007)	Descriptive analysis of farmers' risk perceptions about risky sources
Feder and Umali (1993)	Literature review involving the impacts of risk perception in agricultural innovations
Valeeva et al. (2005)	Cluster analysis with risk perceptions constructed through survey responses

As shown in Table 2.3 and Table 2.4, the models used frequently in both consumer and producer risk perception measurements include factor analyses, descriptive analyses, ANOVA or MANOVA, structural equation models, discrete choice models and various expectation models. Consumer risk perception measurement also frequently involves use of demand models. In the studies of risk perceptions about prices, various expectation models are applied in both consumer and producer contexts. The measures for risk perceptions or attitudes are constructed through psychometric paradigms in which psychological scales are elicited from a pool of questions about people's risk attitudes and risk perceptions, through designed lottery experiments based on expected utility models, or through the real market behaviour where the risk perception is constructed by demand changes after certain risky events have occurred.

2.2.4.1 Risk Perception Measurement through Psychometric Paradigms or Lottery Experiments

The psychometric paradigm and lottery experiments are seen in both consumer and producer studies (Table 2.3 and Table 2.4). The psychometric paradigm typically involves collecting and analyzing individuals' responses to multiple questions about their perceptions of risky events. The responses such as rating and/or ranking are then used to represent the individuals' profiles and analyzed through statistical methods (Slovic, 1979; 1987b). Lottery experiments are conducted for risk perceptions based on various utility hypotheses such as expected (Gunjal and Legault, 1994) or non-expected utility (Quiggin, 1981). It involves designing certain lotteries and eliciting people's choices to evaluate their risk preferences. The lottery experiments for risk perception evaluations are based on hypothetical scenarios while the psychometric paradigm for risk perception evaluations are based on either real or hypothetical scenarios.

Both the psychometric paradigm and lottery experiments can elicit people's risk preference directly. However, they are not without problems. For risk attitude elicitation, according to Gardner and Likert (1967), one issue is related to the capability of correspondents to describe their attitudes or opinions. Alternative forms of the same question need to be asked during surveys to check people's ability to express themselves over different question formats. However, the process of gathering risk attitude data is costly and time-consuming. Another problem is whether the correspondents answer the questions honestly. Further, when developing certain scales or measures for risk attitude questions, two types of error may emerge: "*measurement error*" and "*incorrect theoretical formulation*"

(Bard and Barry, 2000, page 11). As discussed by Cameron and Trivedi (2005, page 46), "*measurement error*" comes from the measured variables as imperfect proxies for the underlying variables. For example, a discrete gender variable may be an imperfect proxy of individuals' productivities in their jobs (Cameron and Trivedi, 2005, page 899). In terms of "*incorrect theoretical formulation*", Spector (1992, page 9) discussed that a scale should behave as predicted by theory. The scale should be *valid* in measuring the theoretical construct it is designed to measure. The "*measurement error*" and "*incorrect theoretical formulation*" need to be checked by reliability tests and validity tests respectively.

Reliability tests evaluate "*how well an experiment, test or any measuring procedure can generate the same results during repeated trials*" (Carmines and Zellner, 1979, page 11). Different methods can be applied for reliability tests such as the "*retest method*", "*alternative form method*", "*split-halves method*", "*internal consistency method*" (Carmines and Zellner, 1979, page 43). The "*Retest method*" is used to test the correlations between the scores from a test (scale or measure) among the same population but at different time periods. If the scores from different time periods are the same, the retest reliability coefficient will be equal to one. The "*Alternative form method*" is used to check the correlations of scores from alternative forms of a test (scale or measure). If the scores from alternative forms of a test (scale or measure) are highly positively correlated, the test (scale or measure) is highly reliable. The "*Split-halves method*" is used to split the sample population and to evaluate the correlation of scores from the sub-sample population. The "*Internal consistency method*" is used to evaluate the correlations of responses from different questions for the same test. If different questions for the same test can generate similar scores, high reliability is suggested. One measure applied for reliability tests is Cronbach's alpha coefficient (Cronbach, 1990; Nunnally and Bernstein, 1994). The Cronbach's alpha coefficient is defined as:

$$alpha = \frac{m}{m-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_y^2}\right), \tag{2.4}$$

where alpha is Cronbach's coefficient, m is the number of items in the scale, σ_i^2 is the variance of the i[th] item and σ_y^2 is the total variance of the m-item scale. The higher the alpha, the more reliable the scales.

Validity tests evaluate "*the extent to which any measuring instrument measures what it is intended to measure*" (Carmines and Zellner, 1979, page 12). Validity indicators include "*construct validity*", "*criterion validity*" and "*content validity*" (Black, 1999, page 298; DeVellis, 2003, page 49). "*Construct validity*" is used to check if the scale applied can elicit different scores from different groups (Bard and Barry, 2000, page 11). Analysis of Variance (ANOVA) can be applied for testing "*construct validity*". If ANOVA suggests significant differences among different groups, "*construct validity*" of the scale is implied. "*Criterion validity*" evaluates whether different instruments for the same theoretical construct can generate similar scores (Devellis, 2003, page 50). If the scales from multiple valid and reliable measures are positively and significantly related, "*Criterion validity*" is indicated. However, the consistency of the scores requires the consistency standards based on the study's objective (Bard and Barry, 2000). "*Content validity*" evaluates whether the content and subjects of question items appropriately represent the tests to be done (Black, 1999, page 300). It is difficult to measure "*content validity*" through an abstracted scale because of the difficulties associated with sampling content and constructing scale (Carmines and Zellner, 1979, p. 21-22).

The exploratory factor analysis can be applied to the tests for "*construct validity*" and "*criterion validity*". The factor analytical model can be represented as a matrix form (Schroeder et al.,2007):

$$x = \beta\kappa + \eta \qquad (2.5)$$

where x is q*1 vectors of n sets of observed variables or indicators, K is n*1 underlying factors such as risk attitudes or risk perceptions, β is q*n matrix of coefficients relating the indicators or observed variables to the underlying factors, and η is q*1 vector of error terms of the indicators or observed variables.

The psychometric paradigm is criticized as having lower explanatory power for variance of risk perceptions and risk tolerance, logic flaws about including dread items into risk perceptions, the weakness of datasets in explaining risk perceptions, and the lack of distinctions of risk perceptions with respect to self and society. However, the psychometric paradigm has provided a common sense approach to understanding risk perceptions. It is useful for policy makers in terms of adjusting objective risks (Sjöberg et al., 2004, page 25-30). Also, it allows the differentiation of different groups of people according to their risk perceptions or attitudes (Slovic, 1987b, page 282).

2.2.4.2 Risk Perception Measurement through Behaviour Changes after Certain Risky Events Have Occurred

This approach can be referred to as the predictive difference approach because it makes use of the differences between predictions or between predictions and real values of behavioural responses to construct risk perception measures. Liu et al. (1998) estimated a demand function or system based on data before a risky event. The estimated demand function or system was used to predict the demand after the risky event. The difference between the predicted demand and the real demand after the risky event was assumed to be an indicator of risk perception deviations from the baseline risk perception before the risky event occurs. Van Ravenswaay and Hoehn (1991) used demand changes due to food safety information as the index of consumer risk perception changes. The approach of constructing the risk perceptions through demand changes after certain risky event occurs may be an attractive way in terms of saving time and cost and avoiding reliability and validity tests, especially when the survey data are not available or are not sufficient to evaluate consumer risk perceptions. However, there may be other factors that affect demand changes after a certain risky event occurs. Therefore, risk perceptions can only be approximated through the demand changes after a certain risky event occurs.

Although this approach has only been applied in demand analysis, it may be adopted to the supply analysis to assess how producer revise their risk perceptions after a certain risky event. It may be a simpler way to track producers’ risk perceptions as compared to the designed surveys or experiments considering its lower cost of implementation.

2.2.5 Empirical Measurement of Evolutions of Risk Perceptions

In terms of the dynamic evolution of individual risk perceptions, the studies are summarized in Table 2.5 and Table 2.6.

Table 2.5 The Empirical Studies about Dynamic Evolutions of Consumer Risk Perceptions

Empirical Studies	Models
Loewenstein and Mather (1990)	A linear regression between the perceived level of the risky events and the current and the lagged objective levels of the risky events is established. Partial adjustment is observed, in which the individuals adjust their risk concerns gradually in response to an increase in the objective level of a risky event.
van Ravenswaay and Hoehn (1991)	Demand model with the risk perception approximated by the price change after occurrence of food risk.
Rogers (1997)	The fourth-order polynomial regression is conducted with the risk concerns as the dependent variables and the time trend as independent variable.
Liu et al. (1998)	Demand model based on prospective reference theory with the deviation of risk perception after certain food contamination constructed as a function of food safety information
Verbeke et al. (1999b)	Probit model with the independent variables as whether the consumer has decreased fresh meat consumption since the BSE-crisis and whether the consumer is intended to decrease fresh meat consumption in the future. The independent variables include demographic profiles of consumers and consumer attention to TV media coverage over meat.
Frewer et al. (2002)	The authors conducted MANOVA analyses on the risk attitudes toward genetic modification of food at 1998, 1999 and 2000. The results show that people's risk perceptions are in line with the intensity of media reports on genetic modified foods, which provides support for Social Amplification of Risk framework.
Lima (2004)	Descriptive analysis over the responses of risk perception questions from designed surveys. The risk perceptions are compared over multiple time periods before and after the incinerators started working.
Setbon et al. (2005)	Bivariate and multivariate analyses are conducted based on the data from two surveys. One was done in 2000 during the peak of BSE crisis and the other 13 months later. People's risk perceptions were changed as reflected by different significance levels of the explanatory variables in the models based on the two time period data.
Mazzocchi[12] (2006)	Demand model with state-space approach
Veeman and Li (2007)	Mean comparison between consumer responses to different risky sources such as BSE, GMO, etc. A decrease for perceptions from BSE (mad cow disease) is seen by comparing the 2003 and 2005 sample. An ordered Probit model suggested certain structural change comparing the 2003 and 2005 sample in terms of the effects of demographic variables on BSE risk perceptions
Schroeder et al.	Confirmatory factor analysis model is applied to measure risk attitudes

[12] Mazzocchi (2006) did not specify the risk perception measures in his model. Instead, he used "food scare". However, his model is useful in estimation of unobservable effects such as BSE risk perceptions jointly with behaviour response equations.

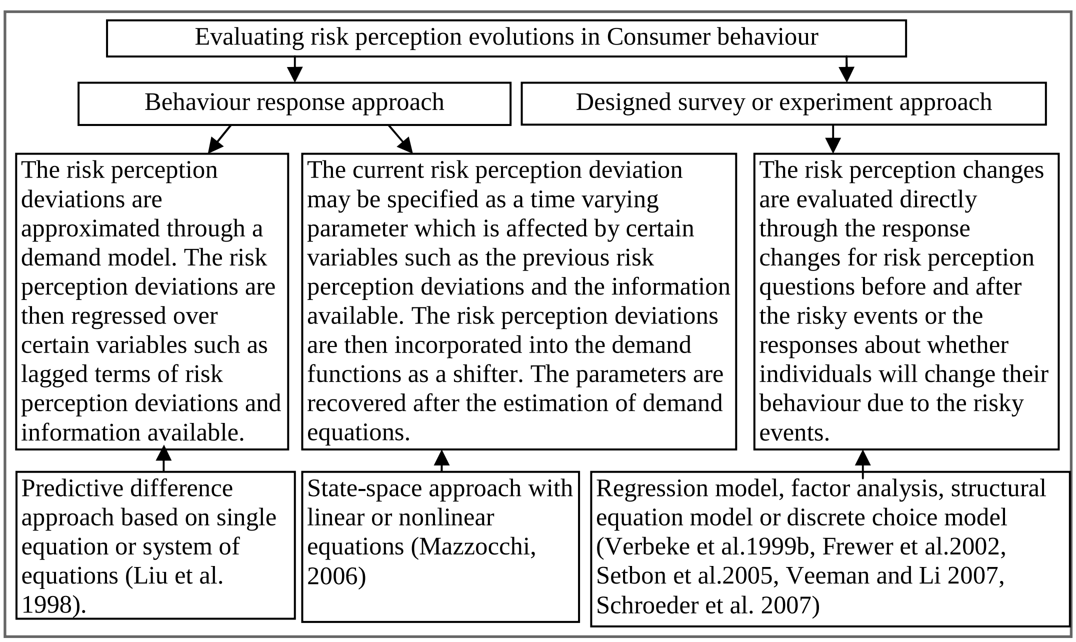
(2007)	and risk perceptions through a pool of questions designed based on psychometric paradigm. The impact of risk attitudes and perceptions on consumer behaviour is analyzed by a two stage model with the first stage as the decision about whether reduce beef consumption over the year from 2002 to 2006 and the second stage as the decision about to what percentage the consumers will reduce their beef consumption.

Table 2.6 The Empirical Studies about Dynamic Evolutions of Producer Risk Perceptions

Empirical Studies	Models or estimation methods
Stoneman (1980), Goodwin and Grennes (1990), Lindner and Gibbs (1990), Leathers and Smale (1991), Fischer ,et al.(1996), Goodhue et al.(1998), Hebert and Goldsmith (2005)	Learning model through designed surveys or experiments

The dynamics of risk perceptions have been analyzed through behavioural response models including predictive difference approaches and state-space approaches, survey or experiment-based models including linear regression models, discrete choice models, descriptive analysis, bivariate and multivariate analysis, Multivariate Analysis of Variance (MNOVA) and learning models. Risk perception changes are measured through real market behaviour changes after risky events, the response changes in risk perception questions before and after risky events or the responses to questions about whether individuals will alter their behaviour due to the risky events (Figure 2.2).

Figure 2.2 The Empirical Approaches to Evaluating Risk Perception Evolutions



2.2.5.1 Behavioural Response Approach

As discussed in previous section, two methods can be applied in behavioural response approaches to analyzing risk perception evolutions of consumers and producers: predictive difference approach (Liu et al., 1998) and state-space approach (Mazzocchi, 2006).

2.2.5.1.1 Predictive Difference Approach

In the predictive difference approach, certain patterns of consumer knowledge updating are assumed such as Prospective Reference Theory (PRT) (Viscusi, 1989)[13]. PRT is based on Bayesian learning of individuals. Given their prior belief A and current belief B, Bayes rule (Bayes, 1763) states that:

$$\text{Probability (A|B)} = \frac{\text{Probability(B | A)} * \text{Probability(A)}}{\text{Probability(B)}} \tag{2.6}$$

Probability (A|B) is called posterior probability. Viscusi (1989) assumed the prior belief and current belief of outcome i as probability Ai and Bi respectively, and the prior and current distribution of trials as a and b respectively. Then, the posterior distribution of outcome i is:

$$\text{Probability (Ai|Bi)} = \frac{a * A_i + b * B_i}{a + b} = \alpha A_i + (1-\alpha) B_i \tag{2.7}$$

where: $\alpha = \frac{a}{a+b}$. Given a lottery with n outcomes, expected utility under the PRT can be specified as (Viscusi, 1989, page 247):

$$EU = \sum_{i=1}^{N} P(C_i) U(D_i) = \alpha \sum_{i=1}^{N} A_i U(D_i) + (1-\alpha) \sum_{i=1}^{N} B_i U(D_i) \ , \tag{2.8}$$

where $P(C_i) = \alpha A_i + (1-\alpha) B_i$ and D_i is the outcome i.

The PRT suggests that given their prior beliefs, people always revise their risk perceptions by the information available through a Bayesian learning process. This view is adopted by Liu et al. (1998), Eom (1994), Stefani and Valli (2004). The current risk perception is represented as a weighted average of the prior belief (reference risk) and the information (stated risk or sample risk) available:

$$POR_{i,t} = \alpha_{i,t} RER_{i,t} + \beta_{i,t} SAR_{i,t} \quad , \tag{2.9}$$

[13] Smith and Desvousges (1988) constructed the risk perceptions through Bayesian learning, which is similar to Prospective Reference theory.

where $\beta_{i,t} = 1 - \alpha_{i,t}$. $POR_{i,t}$ is the individual i's posterior or current risk perception at t; $RER_{i,t}$ is the prior belief or reference risk perception of individual i at t, which may be approximated by the posterior risk perception at t-1. $SAR_{i,t}$ is the information available or sample risk at t for individual i, which may include both the current information and information available at t. $\alpha_{i,t}$ and $\beta_{i,t}$ are parameters of the Bayesian updating process or the weights individual i puts on the prior belief and the information available. For simplicity, these weights are assumed to be invariable across individuals, invariable across time or both. Media attitudes may have various impacts on individuals' risk perceptions.

A negative message may have a larger effect on the risk perception than a positive message. Time can be another factor that affects the self-adjustment of risk perceptions (Kask and Maani, 1992). Considering these factors, Liu et al. (1998) constructed their risk perception equation as:

$$POR_{i,t} = \alpha_{i,t} * RER_{i,t} + \beta_{i,t} * f_{i,t}(N\inf_{i,t-k}, P\inf_{i,t-j}, T) \quad , \quad k,j=0,1,2,\ldots \tag{2.10}$$

where "Ninf" and "Pinf" denote negative and positive information about the risk event. Because the data applied by Liu et al. are time series data, they cannot account for individual specific effects and therefore, assume that people get the same information at every time period and that the weights $\alpha_{i,t}$ and $\beta_{i,t}$ are constant across individuals and time. Taking the first-order differential of posterior risk perceptions, the final model suggested by Liu et al.(1998) is:

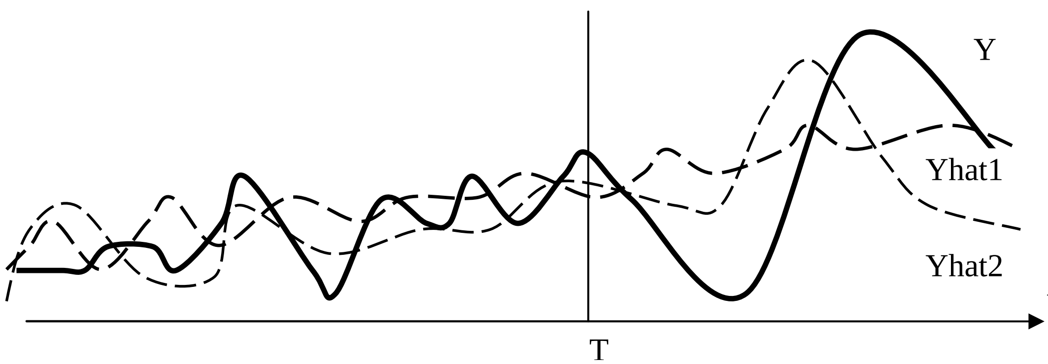
$$devPOR_t = -A_0 * (1-\alpha) + \alpha * devPOR_{t-1} + \beta * f_t(N\inf_{t-k}, P\inf_{t-j}, T) \ , \tag{2.11}$$

where $devPOR_t$ is the deviation of the posterior risk perception at time t from the average baseline risk perception A_0.

The construction of risk perception measures in Liu et al.'s model is arguable. Liu et al. (1998) estimate risk perceptions as the difference between the aggregate predicted and actual consumption in every time period after the risky event divided by the actual consumption in every time period after the risky event. However, the difference between the predicted variable and the real variable may be due to the factors other than the risky events such as other variables or prediction error (Smith and Desvousges, 1988; van Ravenswaay and Hoehn, 1991). This can be illustrated in Figure 2.3.

In Figure 2.3, the dark line is the real value of the variable Y. The dashed line Yhat1 is the prediction from the model based on the data before T. The dashed line Yhat2 is the prediction from the model based on the data for the whole time period. At T, the risk event occurred, leading to possible structural changes in Y. Obviously, if we use the difference between Y and Yhat1 as a measure of risk perceptions, the random errors associated with Y and the effects of factors other than risk perceptions are also included inside the measure of risk perceptions. To reduce the random error from the measure of risk perceptions, the difference between Yhat1 and Yhat2 may be a better proxy for risk perception measures.

Figure 2.3 The Illustration of Predictions based on the Data from Different Time Periods



The construction of information indices in Liu et al.'s model is also questionable. Some researchers propose that regardless of the attitudes in the information, it is the amount of information ("quantity coverage theory") that leads to a negative response from people (Smith et al., 1988; Rowe et al., 2000; Lobb, 2005). However, a counter-argument suggests that contextual, content and social factors also play a part in shaping responses to risk information (Frewer et al., 1999). For example, an article from a medical journal about cancer risk may not have the same impact as the article with the same content but highlighted in the front page of a local newspaper. Based on the SARF, both the quantity (number of media messages) and the quality (the media attitudes, sources, the framing effect, etc.) of information have impacts on risk perceptions. Another important issue is that the individuals may get different amount of information and may have different abilities in processing information (Just and Rausser, 2002, page 59), which were not analyzed in Liu's paper. These problems will be addressed in the model construction section.

2.2.5.1.2 State-space Approach

Under the state-space approach, the model system to be estimated is:

$$y_{i,j,t} = f(\text{prices}_{j,t}, \text{income}_{j,t}, \text{other variables}_{j,t}, POR_{i,j,t}) \quad , \qquad (2.12)$$

where i represents ith equation and j is jth individual. The demand equations including 2.10 and 2.12 can be transformed to either linear or nonlinear state-space forms depending on the functions applied. The problems of the state-space approach are that it is not easy to estimate and that the parameters inside the risk perception equations and the parameters inside the behaviour equations may be mixed and not identifiable. Therefore, certain constraints to gain identification may be required. The empirical estimation methods for the state-space form will be discussed in section 2.6.

The behavioural response approach is used to track changes in risk perceptions over time due to a risky event. Although it has only been seen in demand analysis, it may also be applied to production and supply analysis. However, certain behavioural assumptions are required to construct the risk perceptions and it may be difficult to estimate the behavioural model with a state-space form.

2.2.5.2 Designed Survey or Experiment Approach

The designed survey or experimental approach based on the psychometric paradigm can elicit people's responses directly and can provide the ability to classify people into different groups in terms of their responses to risk perception questions. Given surveys before and after certain risky events, how individuals have changed their risk perceptions could be evaluated. However, as people's knowledge may update continuously given new information available, their risk perceptions may also change over time continuously (see previous section about SARF). Therefore, designed surveys or experiments implemented in several discontinuous time periods may not be sufficient to describe the path of risk perceptions over time. Also, the designed survey or experiment approach based on the psychometric paradigm is subject to several criticisms mentioned before (Sjöberg et al., 2004, page 25-30).

In terms of assessing the evolution of BSE risk perceptions held by Canadians, a designed survey may not be a good choice due to the fact that there were no surveys on people's beef risk perceptions before the BSE outbreak in Canada in 2003. Nonetheless, a survey designed at the current time could be used to group people according to their risk perceptions concerning BSE and provide certain calibrations for a behavioural response model based on these different groups of people. For example, the individual with a high BSE risk perception now may have had different behavioural responses as compared to the one with a low current BSE risk perception.

2.2.6 Summary

Decision-makers including consumers and producers frequently make their decisions under risk or uncertainty. In this chapter, the traditional expected utility and the related concepts such as risk-averse, risk-neutral and risk-seeking are reviewed. As one of the components of expected utility theory, objective probability is criticized due to the fact that people may hold their own beliefs over certain risky events in advance and it suffers from bounded-rationality problems. Therefore, the studies of risk perceptions and the dynamic evolution of risk perceptions are reviewed. Given the insufficiency of economic studies about the dynamics of risk perceptions, a sociological theory named Social Amplification of Risk Framework (SARF) is discussed in terms of risk amplification or attenuation over time when risk signals interact with various social, institutional, individual factors. Media quantity and content play very important roles in SARF. Given risk perception measures, SARF can be empirically tested through the values and significance of parameters on different media information indices.

The empirical methods for constructing measures of risk perceptions and the dynamics of risk perceptions include the behavioural response approach, a designed survey or experiment approach based on the psychometric paradigm, the subjective expectation as well as learning approach. The problems with the designed survey or experiment approach are the extent of reliability and validity, which requires certain tests. Further, discontinuous surveys or experiments may not be sufficient to track risk perception changes over time. However, the designed survey or experiment approach can elicit people's risk perceptions directly and allow people to be classified into different groups in terms of their responses to risk perception questions. The behavioural response approach approximates risk perceptions through behaviour changes after a certain risky event occurs. It may be an attractive way to track risk perception changes over time, saving time and cost and avoiding the reliability and validity tests. However, the impacts of other variables and prediction errors on behaviour changes need to be separated from the impacts of risk perceptions.

BSE risk may have different meaning for consumers and producers. For consumers, BSE may be a food safety risk or food safety scare (Luning et al., 2006, page 619). For producers, BSE may be a risk of income losses or changes in prices due to the temporary shut-down of exports (Dunn, 2004, page 37-41; Mitura and Di Pietro, 2004, page 18). The different implications of BSE risk for consumers and producers require behavioural models or the designed survey approaches to be different. Further, the designed survey approach may provide calibration of behavioural response approach if both are available. It may be possible to classify consumers or producers according to their responses to risk perception questions. Then, the behavioural response approach can be applied to these different groups to analyze and compare how they revise their risk perceptions over time. This chapter therefore, provides some guidance about how to elicit and analyze risk perceptions about BSE.

2.3 Beef Sector

To analyze the impacts of BSE-discovery on the Canadian beef industry, a comprehensive model of the Canadian beef sector is required. In the following sections, the structure of Canadian beef cattle production is discussed and studies of beef and cattle production and supply are reviewed. Further, regarding the integrated nature of the North American beef industry and Canada's high dependence on exports, models of the North American beef sector and international beef trade are also reviewed.

2.3.1 Beef and Cattle Production and Supply

Beef and cattle producers' decision-making is subject to multiple factors apart from prices, such as seasonality, biological constraints and length of time between cow breeding and calf weaning (Jarvis, 1974; Tryfos, 1974; Chan, 1981; Marsh, 1984; Paarsch, 1985; Okyere and Johnson, 1987; Aadland and Bailey, 2001). Cattle output prices are likely to fluctuate greatly within one year partially due to the seasonal patterns in consumption of beef products (Maki, 1957; Johnson et al., 1998; Lomeli, 2005; Kuchler and Tegene, 2006). Under an increase in cattle prices, cattle may be either sold for current profit or kept as assets to breed more calves for a higher return (Jarvis, 1974). The cow inventory decisions will affect the supply of calves in the feeder cattle market, which in turn, will affect the supply of fed cattle for slaughter and ultimately the beef supply. Combined with the biological features of cattle production, the cattle supply and inventory decisions will unavoidably involve certain lags in response to input and output prices, which represent the adjustment costs in the production process. The underlying reasons for cattle cycles have been explained by two schools of thought (Grundmeier et al., 1989): a self-generating model such as the Cobweb model, or an exogenous model where demand, climate, and feed supplies and other exogenous factors play roles (Breimyer, 1955). It takes time for a calf to grow from weaning to slaughtering, leading to a lagged structure in cattle production (Kulshreshtha and Wilson, 1974; Foster and Burt, 1992; Marsh, 1983; 2007).

The determination of price expectations of producers when they make production decisions becomes crucial in modeling beef cattle production and supply. Researchers have used methods such as naive expectations, autoregressive integrated moving average (ARIMA) expectations, futures prices, adaptive expectations, rational and quasi-rational expectations (Nerlove, 1956; 1983; Antonovitz and Green, 1990; Nerlove and Fornari, 1997; Chavas, 2000; Nerlove, 2001), heterogeneous expectations (Chavas, 2000), rational lags (Marsh, 1983; Rucker et al., 1984; Wohlgenant, 1985b), partial adjustment with composite expectations (Shonkwiler and Hinckley, 1985), distributed lags (Javis, 1974;

Kulshreshtha and Wilson, 1974; Okyere and Johnson, 1987) and autoregressive distributed lags (Rosen et al., 1994; Mbaga, 2000). These studies are summarized in Table 2.7.

As illustrated in Table 2.7, different price expectation formations lead to different market equilibrium conditions. Some researchers (Antonovitz and Green, 1990; Chavas, 2000) have compared different expectation formations and found heterogeneity in expectation formations among producers, which may be due to different costs and availability of information. There are no studies yet for the beef sector about how media information about certain risky issues will affect producers' decisions for beef production and supply.

Table 2.7 The Empirical Studies of Beef Cattle Production and Supply

Authors	Model specifications
Javis (1974)	Argentina beef sector :The model includes slaughter number equations and slaughter weight equations for calves, cows, yearlings, heifers, steers, bulls, a calf born equation, two domestic and export demand equations for beef and six identities. Slaughter equations for calves, cows, yearlings, heifers, steers, bulls are constructed as a function of herd size , absolute rural labour force change, percentage of beef slaughter exported to the Great Britain lagged two years, percentage change in climate index, percentage change in beef price, current and lagged variables (lagged five periods) of beef price. The model is specified as distributed lag form.
Kulshreshtha and Wilson (1974)	Canadian beef sector: Cattle supply is specified as a function of lagged price of slaughter, lagged prices of feed grains, price of competing commodities and seasonal dummies in a polynomial distributed lag form.
Marsh (1983)	U.S. beef sector: Feeder steer price is specified as a function of lagged quantity of cattle placed on feed, lagged price of fed steer, lagged price of corn, expected lagged feeder steer prices, seasonal dummies following rational lag form. Fed steer price is specified as a function of commercial cattle slaughter of fed steers and heifers, commercial cattle slaughter of nonfed steers and heifers, steer by product values, wholesale price of steer carcasses, expected lagged fed steer prices, seasonal dummies following rational lag form.
Rucker et al. (1984)	U.S. beef sector: Breeding herd inventory and beef cattle inventory are specified as a function of lagged hay productions to indicate climate changes, lagged Calf prices, lagged corn prices, lagged beef-corn price ratios, expected lagged breeding herd inventories or beef cattle inventories following rational lag form.
Shonkwiler and Hinckley (1985)	U.S. beef sector: Number of cattle placed on feed is specified as a function of lagged and current corn price, time period dummies, current feeder steer price and the rational expectation of current feeder steer price given current information available. The model is a partial adjustment form with a composite expectation as a weighted average of adaptive expectation and rational expectation
Okyere and Johnson (1987)	U.S. beef sector: The number of steers or heifers that come from calves is specified as a function of seasonal and yearly dummies, lagged variables of beef cow inventory and interest rates, The number of heifer for breeding is specified as a function of seasonal and yearly dummies, lagged variables of beef cow inventory adjustment and interest rates. Average cattle carcass weight is specified as a function of seasonal dummies, lagged prices of slaughter cattle and corn, lagged average cattle carcass weight. The supply of slaughter steers (heifers) is specified as a function of seasonal dummies, yearly and price freezing dummies, lagged prices of slaughter cattle, feeder cattle and corn, lagged slaughter steers (heifers) supply, lagged average inventory and the number of calf becoming slaughter steers or heifers. The supply of slaughter beef cows is specified as a function of lagged price and inventory of slaughter beef cows, lagged prices of feeder cattle and corn, seasonal dummies, yearly and price freezing dummies, lagged slaughter beef cow supply, and lagged average beef cow inventory and dairy cow inventory. The price of feeder cattle is specified as a function of lagged prices of slaughter cattle, feeder cattle and corn, interest rate, non-food consumer price index, seasonal dummies, and lagged average number of slaughter heifers and slaughter steers that come from calves. The price of choice slaughter steer is specified as a function of seasonal and price freezing dummies, lagged price of slaughter cattle, changes of retail price of beef, packing house wage rate, lagged by-product allowance for beef, and inventory adjustment of steers. The price of prime slaughter steer is specified as a function of seasonal and price freezing dummies, lagged price of slaughter heifer, changes of retail price of beef, packing house wage rate, lagged by-product

	allowance for beef, and inventory adjustment of heifers. The price of slaughter cow and bulls is specified as a function of seasonal and price freezing dummies, lagged price of slaughter cow and bulls, changes of retail price of beef, packing house wage rate, lagged by-product allowance for beef from last quarter, and inventory adjustment of slaughter cow and bulls. Choice beef retail price is specified as a function of seasonal dummies, population, per capita disposable income, nonfood consumer price index, lagged retail price of choice beef, and lagged average amount of per capita consumption of pork and chicken. The closing stocks of beef is specified as a function of lagged closing stock of beef, seasonal and price freezing dummies, changes of retail price of choice beef, packing house wage rate and lagged by-product allowance for beef, net trade of beef and quantity of beef production.
Antonovitz and Green (1990)	U.S. beef sector: The aggregate bimonthly supply function of fed cattle is specified as a function of bimonthly seasonality dummies, lagged average price of corn and feeder cattle and expected fed cattle price. The naive expectations, ARIMA expectations, futures prices, adaptive expectations, rational expectations are formed and the associated supply function of fed cattle for each expectation formation is derived and estimated empirically. Non-nested statistical test (J-test) suggests that no expectation form is superior to others and heterogeneous expectations exist among producers.
Rosen et al. (1994)	U.S. beef sector: Assuming it takes one year for the calf to be born and takes two years for the calf to get mature and slaughtered, the breeding stock is specified as a function of breeding stock lagged one year and lagged three year, nature death rate, calving rate, and the number adults sent to slaughter following autoregressive distributed lag form. The discounted holding (hold the animal and sell it later) cost is specified as a function of unit holding cost of an adult and the proportional adult equivalent holding cost of calves and yearlings respectively. The gross return from feeding is the sum of expected net return of breeding herd increase after 3 years and expected net return of cattle number increase at next year deducted the death loss of cattle. The ranchers should equalize the values of slaughter and breeding at optimal solutions. The market equilibrium is built on the identity between the cattle supply and cattle demand.
Nerlove and Fornari (1997)	U.S. beef sector: The total calves born are proportional to reproductive cow stock. The cow sold for slaughter is a function of current reproductive herd, deflated sales price of heifers and deflated sales price of steers. The steer sold for slaughter or feedlot placement is a function of current steer stock, deflated sales price of steers, expected deflated sales price of steer in next quarter, and male animals at the age of 1 year. The sum of heifer sold for placement on feed or slaughtering and heifer kept for gross investment (heifers added to the reproductive herd) is specified as a function of current heifer stock, deflated sales price of heifers, expected deflated sales price of heifers in next quarter, and female animals at the age of 1 year. The gross investment (heifers added to the reproductive herd) is a function of current deflated sales price of heifers, deflated sales price of cows, expected deflated sales price of cows in next quarter. The net placement of steers or heifers on feed is specified as a function of current price of feeder steers or heifers, the expected price of fed steers or heifers for slaughter in next quarter, the expected price of corn used for feed in next quarter. The fed cattle marketing is specified as a function of total cattle on feed. The total fed steer and heifer slaughter is specified as a function of fed cattle marketings. Commercial steer and heifer slaughter is specified as a function of reproductive herd lagged five quarters. Assuming the number of fed steer (heifer, nonfed steer, nonfed heifer) slaughter has the same percentage in the number of total fed cattle slaughter as the ratio of federally inspected steer (heifer, nonfed steer, nonfed heifer) slaughter over total federally inspected slaughter, the fed steer (heifer, nonfed steer, nonfed heifer) slaughter is specified as the product between the ratio of federally inspected steer (heifer, nonfed steer, nonfed heifer) slaughter over total federally inspected slaughter and fed steer and heifer slaughter. The nonfed steer and heifer slaughter is specified as commercial steer and heifer slaughter deducted by fed steer and heifer slaughter and cow sold for slaughter. The commercial beef production is computed

	by the product of commercial cattle slaughter and average dressing weight. Market equilibrium is constructed through the beef supply equal to the beef demand plus net exports and net beef stock. The price of fed steer (heifer, nonfed steer, nonfed heifer, cow) for slaughter is specified as a function of retail price of beef and the total cattle for slaughter. Deflated sales price of steer, deflated sales price of heifer, deflated sales price of cow are assumed to follow the autoregressive invertible moving average (ARIMA) structure and their expectations are estimated empirically. These estimates of expectations are plugged into the equations of cow supply and heifer supply equations specified above. The quasi-rational approach has the advantage to avoid the high multicollinearity from the full rational expectations due to substitutions among different equations.
Mbaga (2000)	Canadian beef sector: Assuming that one period is half a year, the output supply and input demand functions are derived from expected profit maximization. Assuming a constant Arrow Pratt Absolute Risk Aversion, the quantity of feeder cattle (cow, replacement heifer, fed cattle) supply is derived as a function of prices of inputs in the last five periods, breeding herd inventory lagged five periods, quantities of feeder cattle (cow, replacement heifer, fed cattle) supply lagged some periods, expectations and variances of feeder cattle (cow, replacement heifer, fed cattle) prices lagged some periods. The decisions of feedlots to purchase feeder cattle is specified as a function of previous feeder cattle purchases, fed cattle prices and input prices. The model is an autoregressive distributed lag model with both of the mean and variance of input and output prices and the lags of dependant variables.
Chavas (2000)	U.S. beef sector: The Euler's equation for a cattle producer is derived given the dynamics of the animal population under optimal management and competitive market conditions. Different expectation formations including rational expectations, quasi-rational expectations, naïve expectations and heterogeneous expectations are specified and the Euler's equation for each expectation form is derived. The beef demand per capita is specified as a function of beef price, and time trend. The aggregate market equilibriums under various expectation formations are established and estimated in structural equation form. The results imply the existence of heterogeneous expectations.
Aadland and Bailey (2001)	U.S. beef sector: The stock of female calves is assumed to be proportional to the number of breeding cows in the last time period. The stock of retained yearly heifers is equal to the fraction of female calves from last period not sold. These biological relationships are specified empirically. The ranch's aggregate input price is assumed to follow a first-order autoregressive process. The calf price received by ranchers is assumed to be proportional to the expected retail price of fed beef in the next period due to the time lags of finishing while the cow/bull price is assumed to be a function of the current retail price of unfed beef because cows don't need to go through finishing procedure. Total domestic consumption of fed beef is given by the total number of calves that were sent to market in the previous period less the net exports of fed beef in the same period. Total domestic consumption of unfed beef is given as the total number of cows sent to slaughter less net exports of unfed beef, without any lagged values. The rancher's profit maximization problem generate that the market value or price of a female calf must be equal to the discounted, expected net value of a cow next period. The market value of an adult female in the current period must equal the expected discounted net market value of the same animal in the next period plus the expected discounted market value of her calf two periods from now.

As far as the Canadian beef industry is concerned, cattle and beef production is described as follows according to Canada Beef Export Federation (2008, page 1).

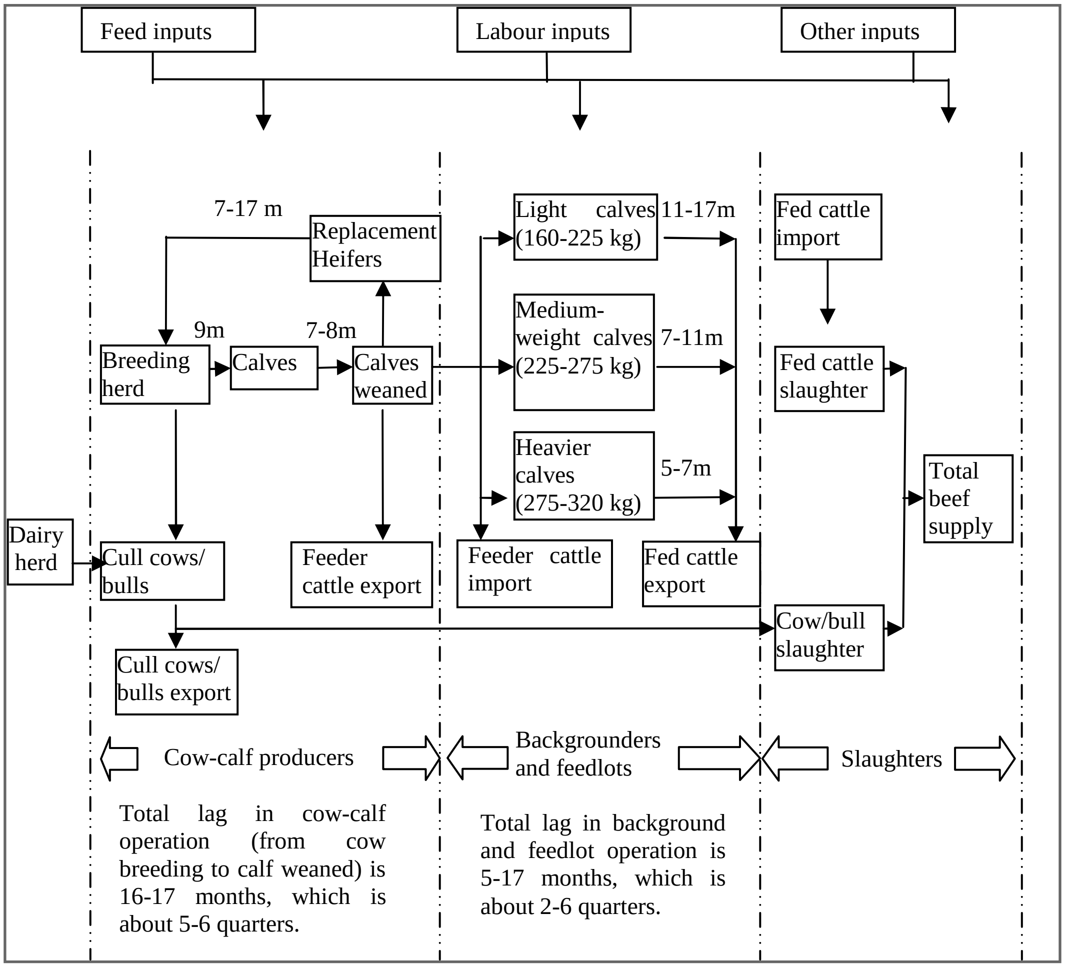
“Cow-calf producers breed cows in early summer and calves are born in following spring. The calves stay with their mothers for grazing throughout the spring, summer, and fall seasons until they reach a weight of 500 to 600 pounds and are weaned. After calves weaned, they are differentiated by their weights and enter different backgrounding and feeding programs for slaughter. The barley-based rations are applied in Western Canada's grain feeding operations while corn and barley are fed in Central and Eastern Canada.

Backgrounding is the process of fattening calves by high forage (alfalfa hay and straw) feeds. At least one half of the calves produced in Canada each year are backgrounded before they start on a high energy feedlot finishing program. Feedlot owners purchase calves or feeder cattle from either cow/calf ranches or backgrounding operations. Only a small portion of the calves produced in Canada are fed to slaughter weights by the original owner of the ranch where they were born.

Feedlots are the final stage of beef cattle production. In feedlot/finishing operation, the feedlots purchase calves or feeder cattle from either cow-calf or backgrounding operations. The calves are then fed under different feeding system and sold to slaughters.”

The Calendar of Canadian cattle production is shown in Figure 2.4. It takes approximately 6 quarters from cattle breeding to calf weaning. Therefore, when cow-calf producers make their inventory decisions, they may use the current price of feeder cattle to construct their adaptive expectations for the price of feeder cattle after 6 quarters.

Figure 2.4 Canadian Cattle Production Calendar



Other factors that may affect cattle supply include input prices, interest rates, demand shifters (Breimyer, 1955; Grundmeier et al., 1989; Nerlove and Fornari, 1997), weather, animal diseases (Nerlove, 1979; Rucker et al., 1984; Paarlberg et al., 2003), and government policies (Nerlove and Bachman, 1960; Skaggs and Falk, 1998). Increases in input prices may decrease the expected profitability of producers and lead to increased slaughter cattle supplies. Interest rates represent the opportunity cost of investment in herd expansion. Demand shifters such as retail prices of other related meats, risk perceptions for food safety issues such as BSE may affect beef retail prices under market equilibrium, which will in turn, affect beef and cattle supplies (Nerlove and Fornari, 1997; Lloyd et al., 2006). The weather may affect the harvest of forages and water supply, leading to declines in herd size and cattle supplies (Rucker et al., 1984). Rucker et al. (1984)

made use of lagged hay production as an indicator of weather conditions and incorporated it into the breeding herd inventory equation. Government policies may also alter cattle supplies. For example, a feed subsidy program can raise beef calf supplies (Skaggs and Falk, 1998).

BSE information may have an impact on producer risk perceptions and therefore, affect their cattle supplies. This has been analyzed by John (2007) by incorporating a BSE dummy (BSE dummy=0 before the first quarter of 2003; =1 otherwise) into slaughter cow/bull supply or slaughter steer/heifer supply equations. However, producers' price expectations may also be affected by the BSE information and the effects may be varying over time. The BSE dummy may not be sufficient to evaluate risk perception changes. Incorporating BSE media information into the behavioural relationships underlying cattle supplies may be a better way.

A producer is assumed to maximize his (her) outputs in a primal approach. In a dual approach, a producer is assumed to maximize his (her) profits or minimize his(her) costs in production given production technology available (Chambers, 1988). Specifically for cow-calf producers, the profit maximization is a dynamic process due to the lags in production cycles, in which the cow inventories and calf supplies are determined (Jarvis, 1974). Considering the factors discussed above, Canadian beef cow inventories can be modeled as a function of expected feeder cattle prices, feed (barley and corn) prices, interest rates, weather, animal diseases, risk perceptions and government policies. The expected feeder cattle prices can be constructed under adaptive expectation hypotheses. If a farmer has adaptive expectations over prices, his(her) current beef cow inventories will be affected by his(her) previous beef cow inventories (Nerlove, 1979). However, the impact of information on the agricultural supply decisions must be taken into account (Just and Rausser, 2002). BSE information may result in an impact on producers' risk perceptions, which in turn, might affect supply decisions. However, producers' risk perceptions related to BSE are not directly observable and need to be evaluated by either a behavioural response approach or a survey/experiment approach.

The interest rates for costs of capital may be represented by the prime bank rates. The weather conditions may be incorporated through the hay production at the time of decision-making (Rucker et al., 1984). Animal diseases such as BSE may result in producers incurring costs to have their cattle tested and disposal of dead animals. CFIA has provided financial support to offset the costs of veterinary examinations and carcass disposal (on farm or dead stock collection) of producers in Canada since 2003. Therefore, test costs may not be a big issue. However, transportation costs are paid by producers to have their dead cattle rendered after BSE-infected cows are identified in Canada due to the losses in profits of rendering plants. The increase in transportation costs may alter the cattle producers' cost structure and its impacts may be captured by a BSE dummy variable with value 1 after May, 2003 and zero otherwise. The government BSE-assistance programs may also play an important role in supply decisions. Many such programs were aimed at alleviating the Canadian cattle slaughter burdens by paying feedlots or cow-calf producers to hold their animals longer, which could have certain impacts on the cattle supply responses. The effects of these programs may be captured by producer subsidy estimates.

Following the same logic as inventory decisions, the slaughter cow/bull supplies are affected by expected feeder cattle prices (or steer and heifer slaughter by expected fed cattle prices), feed (barley and corn) prices, interest rates, weather, animal diseases, and government policies. Because the previous herd inventories can affect current cow/bull and steer/heifer supplies, the lagged breeding herd inventories and lagged milk herd inventories are also variables in slaughter cow/bull supply decisions. The lagged breeding herd inventories are also included in the slaughter steer and heifer supply decisions. BSE information, interest rates, weather, animal diseases, and government policies can be incorporated into the slaughter cow/bull supply and slaughter steer/heifer supply equations in a similar approach as in the inventory equation.

2.3.2 Beef and Cattle Sector Models

2.3.2.1 Theoretical Considerations

In order to analyze BSE impacts on the Canadian beef and cattle industry, a comprehensive model including all sectors in the Canadian beef supply chain and international trade is required. This in turn, demands a review of the literature on beef sector models in Canada and other countries. Generally, beef sector models are built under either a partial equilibrium or a general equilibrium framework (Hertel and Tsigas, 1988; Thurman and Wohlgenant, 1989; Hubbard and Philippidis, 2001; Brester et al., 2002; Philippidis and Hubbard, 2005; Gohin et al., 2006). Under general equilibrium, the production, consumption and prices in a whole economy are analyzed. All goods markets may be included in general equilibrium in some simplified forms. The general equilibrium theory is provided by a model developed jointly by Arrow and Debreu (1954). Computable general equilibrium is one type of general equilibrium in which actual economic data are used under certain behaviour assumptions of consumers and producers to estimate how an economy might react to changes in external factors such as government policies, technical changes, shocks from supplies or demand, etc. General equilibrium approaches usually involve many equations for different parts of the economy and incur a large estimation burden. In partial equilibrium, the price of one good is determined in its market with the assumption that the prices of all other goods held constant.

Using the partial equilibrium model can decrease the estimation burden and focus on the analysis of a certain industry but the assumption of partial equilibrium is seldom true in real world. An equilibrium displacement model (EDM) is one type of partial equilibrium approach where a simultaneous system of equations is constructed, with the elasticity parameters estimated or borrowed from previous studies and the endogenous variables and the exogenous variables measured as proportional changes. The EDM model has been applied for studies assessing the effects of demand or supply shifts caused by advertising, technology, environmental regulation, trade policies, etc.(Gao et al., 1999; Zhao et al., 2002; Zhao et al., 2003; Lusk and Anderson, 2004; Piggott, 2003; Metcalfe, 2000;

Cranfield, 2002; Kinnucan and Myrland, 2002; Brester and Wohlgenant, 1991, 1993; James and Alston, 2002; Mullen and Alston, 1994).

Another issue in the beef sector model is the approach to dealing with international beef and cattle trade. Two general types of models exist in empirical time series trade model literature. One model assumes perfect substitution and the other imperfect substitution. In the aggregate trade model, these two types of models are often looked as competitors and in the disaggregate trade model, in contrast, they can be viewed as complements with one dealing with the close substitutes and another dealing with differentiated products (Goldstein and Khan, 1991). The key assumption in the imperfect substitution model is that neither exports nor imports are perfect substitutes for domestic products or for imports/exports from other countries. It was argued that if there was perfect substitution between the import or export goods and the domestic goods, the country should be only an importer or an exporter (Rhomberg, 1973). It may be argued the transportation costs are one explanation for a country both importing and exporting in different regions. However, in Canada, beef and cattle are both imported and exported in almost each province (Pekalski, 2005). The major trading partner for Canada is U.S. The U.S. boxed beef exports to Canada are of different grade from the imports of Canadian boxed beef to the U.S. (Marsh and Peel, 2002). Certain previous studies on Country Of Origin Labelling (COOL) issues have also revealed that the Canadian beef and cattle are treated differently in sales and production from U.S. domestic produced beef and cattle (Zhang, 2005a; Zhang, 2005b). Because Europe and Japan also have the COOL requirements, differentiation between their domestic produced beef and the imported beef is also expected. As a comparison, Canada allows the voluntary COOL for beef and beef products sold in Canada.

Based on different approaches and assumptions for the beef sector model, various analyses have been done for the beef industry. These studies will be reviewed in the following parts.

2.3.2.2 Empirical Studies

The existing literature review on beef and cattle industry models covers several aspects including the research on the cattle production cycle, the studies of impacts from R&D (research and development), technology changes, beef advertising, import tariffs, or market power as well as price transmission, the studies of COOL impacts and the analyses of the influences of beef or cattle exports (imports) on the domestic beef industry (Rosen et al., 1994; Foster and Burt, 1992; Chan, 1981; Paarsch, 1985; Aadland and Bailey, 2001; Brester et al., 2002; Wohlgenant, 1993; Kinnucan et al., 1996; Brester, 1996; Brester and Marsh, 2001; Cranfield and Goddard, 1999; Wohlgenant and Piggott, 2003). The model construction and the estimation methods applied in beef and cattle industries are partially summarized in Table 2.8.

Table 2.8 The Empirical Studies of Beef Sector

Authors/Studies[14]	Model	Estimation methods
Bartola (1977): A dynamic model of the Italian cattle and beef sector	Linear functional forms of demand and supply equations derived from adaptive expectations.	Single equation estimation.
Grundmeier, Skold et.al.(1989): CARD Livestock Model Documentation: Beef	Partial equilibrium model under three scenarios of trade situations. Beef demand equations are specified as Loglinear functional form. Cow-calf, stock and feeder, beef packing sector and retail market margins equations are specified as linear functional forms derived from adaptive expectations.	Single equation estimation.
Melton and Huffman (1993): NAFTA Impact on U.S. – Mexican beef production and trade	Partial equilibrium model under three scenarios of trade situations. Beef demand equations are specified as Almost Ideal Demand System Cow-calf, stock and feeder sectors are specified as linear functional form derived from adaptive expectations. Beef packing sector equations are derived from a TransLog cost function.	Single equation estimation.
Berg and Reinert (1995): A Computable General Equilibrium Estimation of The Effects of The U.S. Meat Program	Computable General Equilibrium (CGE) model of the U.S. economy.	CGE model
Brester (1996): Estimation of the U.S. Import Demand	Partial equilibrium model with imports as the difference between an aggregate demand function (Rotterdam demand model) and an	Parameters are estimated individually in demand and supply

[14] Some of the beef sector models are included in Table 8 because they are important in the review of cattle production and supply.

Elasticity for Beef: The Importance of Disaggregation	aggregate supply function (linear). Beef production is specified as a linear function of the deflated retail price, farm gate price, and the marketing cost as well as a lagged dependent variable derived from adaptive expectations.	functions
Kinnucan et al. (1996): Welfare Implications of Increased US Beef Promotion	Retail demand functions are specified as Rotterdam functional form. The impacts of health information over demand are evaluated. The impacts of health information over farm supply are evaluated through the price transmission functions.	Seemingly Unrelated Regression.
Cranfield and Goddard (1999): Open Economy and Processor Oligopoly Power Effects of Beef Advertising in Canada	Partial equilibrium model of Canada and the U.S. beef sectors with differentiation between Western Canada and Eastern Canada. Linear demand functions are applied for Canadian and U.S. retail beef demand. Cattle production and supply equations are specified as linear functions following adaptive expectations. Linear price transmission functions among Western Canada, Eastern Canada and the U.S. in terms of live cattle and beef are specified. Slaughter input demand functions for three regions are derived from Generalized Leontief cost functions. Market power coefficients are empirically specified as a function of advertising expenditures and estimated. Trades to rest of the world expect the U.S. and Canada are exogenous.	Retail beef demand, retail price transmission, live cattle demand and industry Lerner Index are estimated simultaneously. The supply equations are estimated by OLS.
Zhao et al.(2003): The Economic Incidence of R&D and Promotion Investments in the Australian Beef Industry.	Equilibrium displacement model of Australian beef industry under twelve investment scenarios.	Parameters are borrowed from other previous studies. Different scenarios of COOL are simulated.
Brester and Marsh (2001):The Effects of U.S. Meat Packing and Livestock Production Technologies on Marketing Margins and Prices	Reduced-form models for beef and pork farm-wholesale marketing margins and cattle and hog prices that include specific measures of technological change are estimated in a system of Loglinear functions.	Iterative Seemingly Unrelated Regression.
Marsh (2003):Impacts of Declining U.S. Retail Beef Demand on Farm-Level Beef Prices and Production	Supply and demand functions for slaughter cattle and feeder cattle are specified as linear functional form following autoregressive distributed lag form. The demand index as an exogenous variable in slaughter equilibrium.	Structural equations estimated by Iterated 3SLS(3-Stage Least Square)
Aadland and Bailey (2001):Short-Run Supply Responses in The U.S. Beef-Cattle Industry	Partial equilibrium model of the U.S. beef sector. The cattle production and supply is derived from profit maximization with dynamic rational expectations. Price mark-up equations between retailers and cow-calf producers for fed cattle and nonfed cattle are specified. Demand equations for fed cattle and nonfed cattle are	Applying Blanchard and Kahn (1980) method for solving linear difference models under rational expectations

	specified as linear functional form.	
Wachenheim et al.(2004): Canadian Exports of Livestock and Meat to the United States	Beef and live cattle trade between the U.S. and Canada is analyzed through a Canadian export supply equation and a U.S. import demand equation.	3-Stage Least Square
Zhang (2005a):The Impact of U.S. Country-Of-Origin Labelling Requirements on The North American Beef Industry	Equilibrium Displacement Model of Canada and the U.S. beef and cattle industries with product differentiation by locations of production (Armington model (Armington,1969)).	Parameters are borrowed from other previous studies. Different scenarios of COOL are simulated.
Zhang (2005b) :Effects of county-of-origin labelling (COOL) in the United States meat industry	Equilibrium Displacement Model for the U.S. beef sector.	Parameters are borrowed from other previous studies. Different scenarios of COOL are simulated.
Holzer (2005): Health(Cholesterol) Information and Economic Effects on The U.S. Beef Industry	Partial equilibrium model with retail sector, boxed beef sector, fed and nonfed cattle as well as feeder cattle sectors. The empirical model is Structural equation model with Autoregressive Distributed Lags(ARDL)	Full Information Maximum Likelihood and Iterative Three Stage Least Squares
Love (2005): An Investigation of the Effects of BSE on The Canadian Cattle and Beef Markets	Partial equilibrium with retail, processor, feedlot sectors. Retailers, processors are assumed to have Leontief production functions (fixed proportions production technology). Feedlot sectors' input demand and output supply are derived from dynamic optimization problem. BSE dummy variable is incorporated into the market power, input demand and output supply functions	Iterated Nonlinear 3-Stage Least Square

The discussion and reviews of the beef sector model suggest that partial equilibrium models including Equilibrium Displacement Models are frequently applied where the beef and cattle supply and the beef and cattle demand are estimated and beef and cattle market equilibria are constructed. The impacts of R&D, COOL, technology changes, beef advertising, import tariffs, health information, or market power as well as price transmission are simulated through the associated demand and supply equations and the resulted changes in market equilibria are estimated. Various authors have used different specifications for beef sector models. For the producer side, autoregressive, autoregressive distributed lag or rational lag models based on adaptive expectations or rational expectations models are often applied. The processors' production or cost functions are often specified as Leontief or TransLog functional forms. For the consumer side, linear, Rotterdam, TransLog and Almost Ideal Demand systems are frequently used. Trade among countries is frequently analyzed through linear export supply and import demand functions. The regression techniques include single equation estimation, seemingly unrelated regression, 3-Stage Least Squares regressions and Full Information Maximum Likelihood. Therefore, in general there are some relatively common approaches which can be used in the estimation and simulation of different interventions in beef sector models.

In the specification of North American beef sector models the most common structure has been a model disaggregated into three supplying regions–Eastern and Western Canada and the U.S., and two consuming regions –Canada and the U.S. (Martin and Haack, 1977; Coleman and Meilke, 1988; Cranfield and Goddard, 1999; John, 2007). The reason for this structure has traditionally been the trade flows that have occurred in the market–cattle flowing from Western Canada into the U.S. and beef flowing into Eastern Canada from the U.S. with much lower trade in live animals across Canada than north south. There has been some variation in this over time and Eastern Canada has also become a net exporter of live cattle to the U.S. up until 2003 and BSE changed some of the traditional trading relationships for a time.

As shown in Tables 2.7 and 2.8, the specification of North American beef sector models almost always includes equations and identities explaining the level of beef cow inventories, the level of slaughter steer/heifer supplies, slaughter cow/bull supplies, carcass weights, beef supplies, slaughter steers/heifers demanded, slaughter cows/bulls demanded, price transmissions from feeder calves to slaughter steers/heifers, price transmissions among different countries, and beef demanded. In many cases trade between Canada and the rest of the world and between the US and the rest of the world is assumed to be exogenous (Coleman and Meilke, 1988; Cranfield and Goddard, 1999; John, 2007). The equations in North American beef sector models are usually estimated using linear functional forms. The parameters estimated are used to create synthetic models to examine the impacts of changes in exogenous variables such as BSE outbreaks, health or food safety information changes, advertising expenditure changes, exchange rate changes and changes in key socioeconomic determinants such as disposable income (Coleman and Meilke, 1988; Cranfield and Goddard, 1999; Zhang, 2005a; Zhang, 2005b; John, 2007; Rude et al., 2007). Therefore, from the previous literature the structure of the North American beef sector model to be used in this research can be based upon the common structure used in many previous studies.

2.3.3 Summary

In livestock production, the biological nature of and seasonality in cattle production and supply have been reviewed and different methods for evaluating cattle production and supply have been discussed. Previous studies of the beef sector are also reviewed including the impacts of prices, technical changes, advertising, tariffs, market power, etc. The empirical models of these studies have also been illustrated. The reviews about the beef cattle production, supply and the North American beef sector models provide certain guidance in the model construction for North American beef industry in this thesis.

Cattle producers may also suffer bounded rationality problems due to the complexity of their decision problems, availability of options, psychology factors in decision-making, etc. Cattle producers may not have perfect information on certain types of disease leading to risky choices. These issues imply that producers may make their decisions on the grounds of their perceived severity of the impacts of disease outbreak such as BSE on their decision variables such as inventory and supply responses.

2.4 BSE Impacts on Beef Sector

In order to analyze BSE impacts on the beef supply chain, the existing literature needs to be reviewed first. In the following sections, the studies of BSE impacts on meat demand and beef and cattle supplies and marketing are reviewed and summarized.

2.4.1 Meat Demand and BSE

As an important food safety factor in beef demand, BSE has drawn more and more attention. Since the BSE explosion in England, many economic studies on the BSE impacts have been conducted. Meat demand changes due to BSE also drew much attention. There are several approaches to modeling BSE impacts on meat demand in the existing literature. These approaches are summarized in Table 2.9.

Table 2.9 The Empirical Studies of BSE Impacts on Consumer Behaviour

Authors	**Methods**
Burton and Young (1996)	A dynamic Almost Ideal Demand System model with current and cumulated BSE information indices incorporated as intercept shifter
Latouche et al. (1998)	Willingness to pay model for beef which would not transmit CJD
Verbeke et al. (1999b)	Probit model with the independent variables as whether the consumer has decreased fresh meat consumption since the BSE-crisis and whether the consumer is intended to decrease fresh meat consumption in the future. The independent variables include demographic profiles of consumers and consumer attention to TV media coverage over meat.
Verbeke and Ward (2001)	A three-equation Almost Ideal Demand System with a media index from TV coverage of meat issues as intercept shifter
Barrena et al. (2002)	Structural equation modeling (Hair et al., 1995) with BSE risk perceptions incorporated as one manifest variable.
Herrmann et al. (2002)	A single semi-log beef demand equations with BSE media coverage is incorporated into the demand model as intercept shifter
Jun and Koo (2003)	Reveal preference tests for structural change by Kruskal-Wallis statistics (Frechette and Jin, 2002)
Peng et al. (2004)	A two stage demand system in which the first stage is Double-Log and the second stage linear approximated almost ideal demand system with a media index of BSE as intercept shifter, a border closure index, seasonality dummy variables, habit formation and time trend.
Lomeli (2005)	A two stage demand system where the first stage is a Double-Log function for total meat expenditure and the second stage is a demand share equation system for different types of meats derived from a Box-Cox indirect utility function with food safety and health information indices incorporated as intercept shifters
Miran and Akgungor (2005)	One single double-log beef demand equation with dummy variables included to identify the possible beef sale loss due to BSE crisis.
Kuchler and Abebayehu (2006)	Linear demand model with BSE announcement as dummy variables
Mazzocchi (2006)	One dummy variable is incorporated into the linear approximated Almost Ideal Demand System as intercept shifter to indicate the occurrences of BSE explosion in England. The parameter on this dummy variable is changing over time to capture the impacts of BSE.
Mutondo and Henneberry (2007)	A Rotterdam demand model with the BSE dummies included
Steiner and Yang (2007)	A Multinomial Logit model with Interaction terms between socio-economic characteristics and the meat attributes such as BSE testing.
Veeman and Li (2007)	Ordered Probit models with consumer rating over different risky issues as dependent variables and demographic variables as independent variables
Schroeder et al. (2007)	A two-stage with first stage as Probit and second stage as double-bounded Tobit model

As reviewed in the table above, different methods have different strengths or limitations in evaluating BSE impacts. The dummy approach assumes that the BSE-led structural changes are discontinuous and permanent, which may not be true. The intercept shifter approach is capable of identifying the parallel movement of meat demand but not capable of finding the impacts of BSE in the slope parameters of the demand model. The survey approach may be a better alternative in terms of eliciting people's risk preferences and attitudes. However, the approach requires the design and implementation of a survey which is both time-consuming and costly. Also, the survey must be tested for reliability and validity. Further, the survey approach may not be sufficient to characterize continuous changes in consumer risk perceptions. In terms of BSE, the fact that we don't know in advance that BSE will occur in Canada makes it difficult to generate the before and after measures of risk perceptions. The nonparametric approach for testing preference changes is also subject to criticism such as few number of violations for revealed preference axioms can be found in aggregate time series consumption data (Varian, 1982; Landsburg, 1981) and a lack of suitable measures for significance of violations of the axioms of reveal preference (Choi and Sosin, 1992). The time-varying parameter approach may be used to capture the dynamic changes in consumer demand after BSE outbreaks but may be difficult to estimate.

Regarding these limitations, in this thesis, structural changes due to BSE outbreaks will be tested through the possible changes of both intercepts and the slope parameters within the demand system and both parametric and non-parametric methods will be applied for structural break tests. The BSE risk perception measures will be evaluated through the demand model. The empirical approaches to evaluate the dynamics of risk perceptions reviewed in the risk perception chapter will be applied to BSE risk perception and consumer behaviour analysis.

2.4.2 Beef and Cattle Production, Marketing and BSE

As an important factor contributing to structural changes within the beef industry, the BSE outbreak has drawn much attention. The empirical studies of BSE impacts on beef and cattle production and marketing are summarized in Table 2.10.

Table 2.10 The Empirical Studies about BSE in Beef and Cattle Production and Marketing

Author	Methods
Leeming and Turner (2003)	System of equations of prices of cattle, sheep and pig with dummy variables of BSE outbreak
Mitura and Di Pietro (2004)	Certain scenario is simulated for farm family income losses due to BSE in different types of farms
Mattson and Koo (2005)	Equations on slaughter and feeder steer, retail beef price, imports from Canada and rest of the world are estimated simultaneously with dummy variable for ban on U.S. beef imports from Canada.
Marsh et al. (2005)	System of equations of slaughter sector and feeder sector demand and supply. The BSE impacts are simulated
Coffey et al. (2005) ; Roy and Klein (2005)	Data description
Cox et al. (2005)	Decision trees and probabilities of scenarios to simulate BSE impacts
Love (2005)	Dummy variable for the BSE outbreak is incorporated into the input demand, output supply and the market power equations of cow-calf producers, feedlots and processors (please refer Table 9 for details)
Lloyd et al. (2006)	The impact of BSE in price transmissions is evaluated through related demand shocks
Miljkovic (2006)	Market integration analysis through price cointegration test
Samarajeewa et al. (2006)	An input-output model to evaluate the BSE impacts over Canadian economy at the provincial level through simulations
Park et al. (2006)	Multiregional Input-Output type model. BSE impacts are simulated
Sparling and Caswell (2006)	Data description
Yeboah et al. (2007)	A US Input-Output (I-O) model with different scenarios to simulated BSE impacts.
Boonsaeng and Wohlgenant (2007)	A multi-market partial equilibrium model for simulation of BSE impacts.
John (2007)	A partial equilibrium model with BSE dummy incorporated into the market power estimation and demand as well as supply equations.

As reviewed in the table above, most of the existing studies of the BSE impacts on the beef and cattle sectors have focused on international beef and cattle trade, using the methods of simulation or dummy variable approaches to evaluate BSE impacts. The simulation methods applied for the BSE impact evaluations assume the parameters are invariable over time and there are no structural changes after BSE. The dummy variable approach is only useful in identifying the discontinuous, once-and-for-all structural changes due to BSE. Except for these shortcomings, the two approaches above also ignore the impacts of media information about BSE on producers' risk perceptions and behavioural responses. To overcome these shortages, the structural breaks due to BSE will be evaluated through the parameters of producer behavioural equations. The methods discussed in risk perception section will be applied to construct a producers' risk perception measure and the impacts of BSE media information will be analyzed empirically.

2.4.3 Summary

Disease outbreaks such as BSE may alter people's preferences and present structural changes in their consumption. The empirical approaches of analyzing the impacts of BSE on consumer demand have been illustrated and compared. In the analyses of BSE impacts on meat demand, it was revealed that the current studies about BSE impacts on Canadian meat demand have not addressed the structural breaks in meat demand due to BSE discovery in Canada in a sufficient way regarding changing patterns of consumer risk perceptions of BSE. The impacts of BSE information on consumer risk perceptions also need to be analyzed.

The literature about the impacts of the BSE outbreak on producers' decision-making has also been reviewed and the empirical methods discussed. It has been shown that BSE impacts on the beef industry and producers' behaviour have not been analyzed sufficiently in terms of the structural changes and producer risk perceptions. These issues will be addressed in the empirical analyses of this thesis. Producers' risk perceptions and the impacts of BSE information on producers' risk perceptions will be measured through the approach discussed in the producer risk perception section.

2.5 Econometric Issues: Bayesian Econometrics

Certain restrictions such as negativity, monotonicity are required in models of a rational consumer, producer or processor. Negativity implies the bordered Hessian matrix of a cost function should be quasi-concave and monotonicity implies that the derivatives of cost with respect to input prices should be larger than zero. These restrictions are not equality constraints and imposing them globally over flexible functional forms can reduce their flexibility[15](Diewert and Wales, 1987). Bayesian approaches however, can solve these issues by imposing nonequal restrictions and maintaining the flexibility of functional forms (Terrell, 1996). Another important advantage of the Bayesian approach is that it can be applied to the estimation of complex models such as state-space models, hierarchical models, etc. If the risk perception measure is to be incorporated into a demand system and is to be assumed to be evolving over time, the demand system is in fact a non-linear state-space model. The non-linear state-space model can be estimated through the non-centered Kalman Filter (Harvey, 1991) or Monte Carlo Filter (Tanizaki and Mariano, 1994) that involves complex program coding in Matlab. The Bayesian approach provides one alternative for the estimation of a non-linear state-space model by MCMC algorithm through Gibbs sampling. In the following sections, we will compare the traditional econometric approach (frequentist) and Bayesian approach in section 2.5.1. We then discuss Bayesian econometrics in section 2.5.2.

2.5.1 Comparison between Frequentist and Bayesian

To compare the difference between frequentist and Bayesian estimates, it is necessary to discuss the definitions of probability in the two schools. Given the sample space as the set of all outcomes in an experiment, the frequency or classical probability is to interpret the probability of certain outcome A as the ratio of the number of outcome A occurred in the sample space over the total number of outcomes in the sample space (Bluman, 2005). The frequency definition of probability is also called objective probability where the probabilities represent the limits of relative frequency of certain outcomes as the number of observations approaches infinity. Therefore, the relative frequency of certain outcomes in a large number of trials can approximate its objective probability (Kmenta, 1997). Bayesian probability theory, in contrast, explains probability as a degree of belief (Bernardo and Smith, 1994; Jaynes, 1996); the extent to which a person believes an outcome is true. The subjective nature of beliefs renders all the

[15] Imposing these restrictions locally by the approach of Ryan and Wales (1998) may be attractive but is subject to certain functional forms. As they discussed, for the basic form of TransLog functions, their approach is not applicable.

probabilities appearing in Bayesian probability theory conditional. In particular, under the belief interpretation, probability is not an objective property of some physical or engineering setting, but is conditional to the prior beliefs of individuals (Valpola, 2000; Koop, 2003; Lancaster, 2004, page 7; Greenberg, 2007, page 24; Koop et al., 2007, page 11).

To differentiate between the frequentist and Bayesian approaches, it is necessary to explain Bayes' inference. The uncertainty about the value of the parameter α is modeled by introducing a density p(α) for the prior distribution (Greenberg, 2007, page 12), which expresses the subjective beliefs about the true unknown parameters. The other component of Bayesian theory is the sample joint density or likelihood p(y|α), where y is the vector of observations of dependent variables. If the exogenous regressors X are to be considered, the sample joint density or likelihood becomes p(y|X, α). If there are no data available, all we have is a prior distribution. If the data are observed, the frequency approach is to estimate the unknown parameter α using the maximum likelihood principle. The Bayesian approach instead combines the likelihood of the sample with the prior, reflecting the view that any prior information should be incorporated when considering the probability distributions. The distribution of α can be derived after the combining the likelihood and the prior, which is called a posterior distribution. This can be illustrated through the Bayes' theorem.

$$p(\alpha|y)= p(y|\alpha)*p(\alpha) / p(y) \qquad (2.13)$$

where p(y) denotes the marginal probability distribution of y and

$$p(y) = \int_{S(\alpha)} p(y \mid \alpha)p(\alpha)d\alpha \quad \text{where } S(\alpha) \text{ is the support of } p(\alpha). \qquad (2.14)$$

Because p(y) is free of α, the probability p(α|y) is proportional to the product of the sample likelihood L(y|α) or probability density function p(y|α) and the prior p(α) (Koop, 2003; Lancaster, 2004, page 7; Greenberg, 2007, page 24; Koop et al., 2007, page 11), we have:

$$p(\alpha|y) \propto L(y|\alpha)\, p(\alpha) \qquad (2.15)$$

This representation explains the difference between frequentist and Bayesian approaches. In the frequentist approach, the true value of the parameter is constant but parameter estimates are treated as random variables. In contrast, in the Bayesian approach the parameter is treated as random (Cameron and Trivedi, 2005, page 421). Therefore, the frequency approach makes use of the sample likelihood $L(y|\alpha)$ to estimate the value of α but the Bayesian approach makes use of the posterior probability $p(\alpha|y)$ to estimate the value of α.

Inference about α can be made through the posterior $p(\alpha|y)$. For example, the posterior mean of the parameter α as a Bayesian point estimator is:

$$E(\alpha|y)=\int \alpha p(\alpha|y)d\alpha. \tag{2.16}$$

The integration of the expectation $E(\alpha|y)$ may present a big problem but certain numerical solutions or simulation solution (Train, 2003) may be applied for such integrals.

As compared to the traditional frequency approach, Bayesian inference can incorporate people's prior beliefs into the model as the priors of parameters and can be more flexible in terms of model specifications, underlying parameter distributions and hypotheses testing (Congdon, 2003, page 2).

2.5.2 Applications of Bayesian Econometrics

2.5.2.1 Imposing inequality restrictions

One issue frequently seen in traditional econometrics is the imposition of inequality constraints implied by economic theory such as monotonicity, non-negativity, etc. The estimation subject to these inequality constraints can be done through a quadratic programming approach (Judge and Takayama, 1966; Gallant and Golub, 1984; Hazilla and Kopp, 1986; Wolak, 1989). However, the imposition of inequality restrictions through a quadratic programming approach may generate parameters that are binding over the inequality constraints and may lead to unreasonable estimations of demand functions (Chalfant et al., 1991). Also, imposing the inequality conditions such as curvature globally will destroy the flexibility of functional forms (Diewert and Wales, 1987).

In the Bayesian approach, the inequality restrictions can be incorporated into model estimation through the specification of the prior density. Under the method of the Markov Chain Monte Carlo method, this may be accomplished by the use of an accept-reject algorithm in which a random draw through the posterior density simulator is accepted if it satisfies the inequality restrictions and rejected if the random draw fails to satisfy the inequality conditions (Terrell, 1996; Chalfant et al., 1991). The informative prior is specified as $p_1(\alpha)=D(\alpha)p_0(\alpha)$, where $D(\alpha)$ is the dummy which is equal to 1 if the parameter α estimated satisfy the inequality constraints and 0 if the parameter α estimated fail to satisfy the inequality constraints; $p_0(\alpha)$ is the noninformative prior of α. The posterior inference of the parameter α can be made given the informative prior $p_1(\alpha)$ and the sample likelihood $L(\alpha|y)$ based on observation data.

2.5.2.2 Selection among Different Models

It is an important issue to select among different functional forms in demand or production analyses. To select models nested in a more general form, several tests can be used including the F test, likelihood ratio test and Lagrange Multiplier test. However, it is a problem to select among non-nested flexible functional forms such as TransLog, Almost Ideal, Generalized Leontief, which are often applied to approximate the true and unknown indirect utility functions or production functions. The traditional model selection problem of choosing from a set of non-nested flexible functional forms is based on the encompassing principle (Mizon and Richard, 1986), in which the linear combinations of the non-nested models are estimated and the test of different functional forms can be made (Doran,1993; Lewbel,1989). Some statistical tests have been suggested such as the J test (Davidson and MacKinnon, 1993) or Cox test (1962). For a finite sample, it may be possible in J test that both of the null and alternative hypotheses are rejected or neither of them is rejected but with an increase in sample size, the problem disappears (Davidson and MacKinnon, 1993). Other approaches include comparing adjusted R-squared, Akaike information criterion and Bayesian information criterion from different models. Based on Greene (2005), the adjusted R-squared statistics is specified as:

$$R_a^2 = 1 - \frac{N-1}{N-m}(1-R^2) \qquad (2.17)$$

where N is the number of observations and m is the number of parameters inside of the model. R^2 is the R-squared statistics from the model estimation. Adjusted

R-squared can be used to correct the overfiting tendency due to adding new variables into the model.

The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) are specified as:

$$AIC(m) = \log(SSR / N) + 2 * m / N \tag{2.18}$$

$$BIC(m) = \log(SSR / N) + m * \log(N) / N \tag{2.19}$$

where SSR is the sum of squared residuals.

Bayesian model selection makes use of the posterior odds ratios or Bayesian factors (Kass and Raftery, 1995; Lancaster, 2004, page 97; Cameron and Trivedi, 2005, page 456). Given two hypothesis H_0 and H_1 from different functional forms, the posterior odds ratio O will take the form:

$$O=p(H_0|y)/ p(H_1|y) \tag{2.20}$$

p(H|y) is the posterior distribution of H. The posterior odds ratio O can reflect the ratio of the probabilities of the two models given the observed data. Different from the frequency approach, the posterior odds ratio doesn't need to specify which one of H_0 and H_1 is the null hypothesis.

Another important criterion under Bayesian approach is Deviance Information Criterion (DIC), which is proposed by Spiegelhalter et al.(2002). Let y as the observations and a as the parameter vector to be estimated, DIC is proposed as:

$$DIC= D(\overline{\alpha}) +2\, p_D = \overline{D(\alpha)} + p_D = \text{"goodness of fit"}+\text{"complexity"} \tag{2.21}$$

where p_D = $\overline{D(\alpha)}$ - $D(\overline{\alpha})$, which is defined as *the effective number of parameters* and measures the complexity of the model. $D(\alpha) = -2\log p(y \mid \alpha)$, which measures the "goodness of fit" of the model. $\overline{D(\alpha)}$ is the posterior mean deviance and $D(\overline{\alpha})$ is the deviance of posterior means. The model with the smallest DIC is the model that will produce best prediction given currently observations (The BUGS Project, 2007).

There is no definite conclusion about which criteria is better among AIC, BIC, posterior odds ratio and DIC. However, As discussed by Spiegelhalter et al.(2002), DIC is a certain type of generalization of AIC. Both of BIC and AIC need to specify how many parameters to be estimated, but DIC determines the effective number of parameters during estimation. DIC is specifically useful for complex models such as hierarchical models.

2.5.2.3 Monte Carlo Markov Chain and Gibbs Sampling

The Bayesian approach frequently runs into the integration problem over high dimensions. There are two ways to solve it: numerical quadrature and Monte Carlo Marko Chain (MCMC) methods (Bauwens et al., 1999, page 83; Congdon, 2003; Lancaster, 2004, page 192; Cameron and Trivedi, 2005, page 446; Greenberg, 2007, page 76). The numerical quadrature methods are very computationally demanding and impossible if the dimensions of integration are very high. The MCMC method provides an alternative to avoid the complexity of numerical integration. Given a dataset y and the parameter a_i which is a random sample from density f(a|y), Monte Carlo integration (Gilks et al., 1996, page 4) suggests that:

$$E(f(a \mid y)) \approx \frac{1}{n}\sum_{i=1}^{n} f(a_i \mid y) \qquad (2.22)$$

As n goes to infinity, the right hand side of the above equation converges to the left hand side. It is not easy to draw a_i if a_i is a vector and the posterior distribution function $f(a_i|y)$ is not of the standard form. However, it is often easy to draw $f(a_{i1}|y, a_{i2}\ a_{i3}, \ldots, a_{in})$, $f(a_{i2}|y, a_{i1}\ a_{i3}, \ldots, a_{in}), \ldots, f(a_{in}|y, a_{i1}\ a_{i3}, \ldots, a_{in})$ as full conditional posterior distributions (Gilks et al., 1996, page 4) . One way to do that is via a Markov Chain method.

A Markov Chain specifies a method for generating a sequence of random variables $\{ A_1, A_2, \ldots A_n \}$ with *Markov property* (Markov, 1971) so that:

$$f(A_{it} = a_{it}|A_{i1} = a_{i1}, A_{i2}=a_{i2}, A_{i3}=a_{i3}, \ldots, A_{it-1}=a_{it-1}) = f(A_{it} = a_{it}| A_{it-1} = a_{it-1}) \quad (2.17)$$

Starting from the initial point $a_{i1,}$ the conditional distributions of $a_{i,t+1}|a_{i,t}$ can be generated through a distribution function $a_{i,t+1} \sim F(a_{i,t})$ and the joint posterior distribution $f(a_i|y)$ can be computed. The fact that the conditional distribution only depends on the last a_i greatly simplifies the simulation and analysis of the chain (Rossi et al., 2005). Under some conditions on the conditional distribution F

(Tierney, 1994), $f(a_{it}|a_{i1})$ will converge to a fixed and unique distribution when n goes to infinity.

Gibbs sampling (Cameron and Trivedi, 2005, page 448; Greenberg, 2007, page 91) is a MCMC method, which draws the values of parameters in a sequential way from some conditional density. Given n parameters of a,

$a'=(a_1, a_2, \ldots, a_n)$

Gibbs sampler is defined by iterative sampling from each of these n conditional distributions.

Set a start value of a as a^0

For i=1,…T, draw:

$$a_1^i \sim f(a_1 \mid y, a_2^{i-1}, a_3^{i-1}, \ldots, a_n^{i-1})$$

$$a_2^i \sim f(a_2 \mid y, a_1^i, a_3^{i-1}, \ldots, a_n^{i-1})$$

.

.

$$a_n^i \sim f(a_n \mid y, a_1^i, a_2^i, a_3^i, \ldots, a_{n-1}^i) \tag{2.18}$$

The T draws of parameter α are averaged to create the posterior distribution of α.

$$E(f(a \mid y)) \approx \frac{1}{T}\sum_{i=1}^{T} f(a^i \mid y) \tag{2.19}$$

2.5.2.4 State-Space Models and Gibbs Sampling

2.5.2.4.1 State-Space Models Based on Time Series Data, Kalman Filter and Gibbs Sampling

The state-space approach is very useful for dynamic modeling. A state-space model has two types of equations: measurement equations and transition equations (Harvey, 1993). A measurement equation tracks the relationship among state vectors. A transition equation tracks the relationship among time-varying vectors. Given the data of dependent variables y and independent variables x and associated parameters a, the measurement equation and the transition equation can be illustrated as follows (Lütkepohl, 1993, page 426; Tanizaki and Mariano, 1994):

$y_t = g_t(a_t, x_t, \varepsilon_t)$ Measurement equation

$a_t = k_t(a_{t-1}, \eta_t)$ Transition equation (2.20)

ε_t,η_t are the random error terms. If the measurement equation and the transition equation are linear, the linear state-space model can be expressed as (Harvey, 1991, page 100; Lütkepohl, 1993, page 428):

Measurement equation $y_t = x_t a_t + \varepsilon_t$

Transition equation $a_t = L_t a_{t-1} + D_t \eta_t$ (2.21)

where t=1,…T, $E(a_0)=a$, $Var(a_0)=Q_0$, $E(\varepsilon_t)=0$, $Var(\varepsilon_t)=B_t$, $E(\eta_t)=0$, $Var(\eta_t)=C_t$, $E(\varepsilon_t\eta_s)=0$, $E(\varepsilon_t a_0)=0$, $E(\eta_s a_0)=0$.

A Kalman Filter algorithm (Kalman, 1960) can be applied in the estimation. Defining the optimal estimator of a_t as a_t^*, the mean square error of a_t is:

$$M_t = E[(a_t - a_t^*)((a_t - a_t^*)'] \quad (2.22)$$

Given a_{t-1}^* and M_{t-1}, we have the prediction of a_t^* and M_t as:

$$a_{t|t-1}^* = L_t a_{t-1}^*$$

$$M_{t|t-1} = L_t M_{t-1} L_t' + D_t C_t D_t' \quad (2.23)$$

The estimator of y_t is :

$$\hat{y}_{t|t-1} = x_t a_{t|t-1}^* \quad (2.24)$$

The prediction error is:

$$y_t - \hat{y}_{t|t-1} = x_t(a_t - a_{t|t-1}^*) + \varepsilon_t \quad (2.25)$$

And the mean square error of prediction error is:

$$G_t = x_t M_{t|t-1} x_t' + B_t \quad (2.26)$$

Given the new observations, the estimators of a_t and M_t are updated through:

Prediction and updating equation $a_t^* = a_{t|t-1}^* + M_{t|t-1} x_t G_t^{-1}(y_t - x_t a_{t|t-1}^*)$

Prediction and updating equation $M_t = M_{t|t-1} - M_{t|t-1} x_t G_t^{-1} x_t' M_{t|t-1}$ (2.27)

The predictions of the next time period given a_t and M_t can be constructed through the above prediction equation.

To account for the information available after time t, a smoothing algorithm can be applied to smooth the parameters and mean square errors. The smoothing algorithm is a backward algorithm starting from the final period and is similar to filter algorithm.

The Kalman Filter approach cannot be applied to nonlinear state-space model like equation 2.13. Instead, an extended Kalman filter (EKF) (Durbin, 2004, page 18) in which the measurement equation or Transition equation or both are linearized through Taylor series can be applied.

The extended Kalman Filter approach will only approximate the nonlinear state-space model. Bayesian method presents an attractive alternative to linear and nonlinear state-space model estimation (Tsay, 2005, page 177). Specifically, for the nonlinear state-space model 2.13, the prediction and updating equation are (Anderson and Moore, 1979):

$$P(a_t^* \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots, y_1, x_1) = \int P(a_t^* \mid a_{t-1}^*) P(a_{t-1}^* \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots, y_1, x_1) da_{t-1}^* \quad \text{Prediction equation}$$

$$P(a_t^* \mid y_t, x_t, y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots, y_1, x_1) = \frac{P(y_t, x_t \mid a_t^*) P(a_t^* \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots, y_1, x_1)}{\int P(y_t, x_t \mid a_t^*) P(a_t^* \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots, y_1, x_1) da_{t-1}^*} \quad \text{Updating equation} \qquad (2.28)$$

The probability distribution $P(a_t^* \mid a_{t-1}^*)$ and $P(y_t, x_t \mid a_t^*)$ can be generated through 2.13 given the distributions of ε_t, η_t. The prediction of a_t^* for the next period can be derived through the prediction equation directly. The integration of the probability distributions above can be realized by Gibbs sampling as proposed by Carlin et al.(1992). The linear state-space model can also be estimated through the equation 2.14 by Gibbs sampling.

2.5.2.4.2 State-Space Models Based on Panel Data and Gibbs Sampling

In terms of the state-space models based on panel data, there are few studies except Heiss (2007) and Lachaab et al. (2006). As Heiss discussed, the prediction and updating equations of a state-space model based on panel data can be expressed as:

$$P(a_{i,t}^* \mid y_{i,t-1}, x_{i,t-1}, y_{i,t-2}, x_{i,t-2}, \ldots, y_{i,1}, x_{i,1}) = \int P(a_{i,t}^* \mid a_{i,t-1}^*) P(a_{i,t-1}^* \mid y_{i,t-1}, x_{i,t-1}, y_{i,t-2}, x_{i,t-2}, \ldots, y_{i,1}, x_{i,1}) da_{i,t-1}^* \quad \text{Prediction equation}$$

$$P(a^*_{i,t} \mid y_{i,t}, x_{i,t}, y_{i,t-1}, x_{i,t-1}, y_{i,t-2}, x_{i,t-2}, ..., y_{i,1}, x_{i,1})$$
$$= \frac{P(y_{i,t}, x_{i,t} \mid a^*_{i,t}) P(a^*_{i,t} \mid y_{i,t-1}, x_{i,t-1}, y_{i,t-2}, x_{i,t-2}, ..., y_{i,1}, x_{i,1})}{\int P(y_{i,t}, x_{i,t} \mid a^*_{i,t}) P(a^*_{i,t} \mid y_{i,t-1}, x_{i,t-1}, y_{i,t-2}, x_{i,t-2}, ..., y_{i,1}, x_{i,1}) da^*_{i,t-1}}$$ Updating equation

(2.29)

where i represents individual i. The equation above can be integrated numerically through Gaussian quadrature. However, if the dimensions of integration are very high, the numerical methods are challenging. The Bayesian methods through Gibbs sampling avoids the integration problem by simulating the integrals. Although it is still computationally demanding, the Gibbs sampling provides a relative easier way to estimate the probability distributions above.

Another application of Bayesian methods in panel data is tracking the preference evolution in discrete choice model (Lachaab et al., 2006). The underlying utility function is specified the same form as the linear state-space model and the model is estimated through Gibbs sampling and other related methods.

2.5.3 Summary

The empirical methods for model estimation including frequentist and Bayesian are overviewed and compared. The methods of imposing inequality conditions based on economic theory and the methods of model selections are also discussed in terms of frequency approach and Bayesian approach. The Markov Chain Monte Carlo (MCMC) method of integration and simulation is also illustrated and as one example of MCMC, Gibbs sampling is discussed. The state-space model is also reviewed and the Bayesian estimation of the state-space model by Gibbs sampler is presented, which provides the tools of model estimation for this thesis.

2.6 Chapter Summary

The review of different theories in this chapter renders a basis for the following chapters in terms of conceptual model construction. First, choice under uncertainty and expected utility theory is illustrated and criticized due to the objective nature of probabilities. Risk perception theory is then reviewed. It is suggested that it is perceived risk, instead of objective risk, that frames people's behaviour. The review about risk perception theory suggests that risk perceptions are determined by many factors such as objective risk and psychological factors (representativeness, availability bias and anchoring effect). Among the psychological factors, availability bias as implied by media coverage on certain risky issues has an apparent connection with a high level risk perception. Risk perception is not only affected by the amount of information but also the quality of information. With the effects of media coverage, demographic, social and psychological factors, risk perceptions may not be constant over time. Given these implications, one sociology theory called the Social Amplification of Risk Framework (SARF) is reviewed and will be tested by risk perception measures. Empirical studies about consumer and producer risk perceptions and their evolution over time are then summarized. Different approaches to evaluating consumer and producer risk perceptions are illustrated including the behavioural response approach and survey or experimental approach. These approaches are compared and the advantages of the behavioural response model approach are illustrated. Two methods of behavioural response model approaches are discussed including the predictive difference approach and the state-space approach. Risk perception theory therefore provides certain guidance about how to elicit and analyze risk perceptions about BSE dynamically.

Second, the Canadian beef sector is introduced and the studies of beef cattle production, supply and marketing are reviewed. Specifically in livestock production, the biological nature and seasonality in cattle production are reviewed and different methods for evaluating the decision-making of cow-calf producers, feedlots and processors are discussed. Different studies in beef sectors such as the impacts of prices, technical changes, advertising, tariffs, and market power are reviewed. The empirical models of these studies are also illustrated.

Third, to track BSE impacts, the literature about the impacts of BSE outbreaks on meat consumers and beef producers' decision-making is reviewed and the empirical methods are discussed. It is concluded that BSE impacts on meat consumers and beef producers' behaviour have not been analyzed sufficiently in terms of the structural changes and risk perceptions. These issues will be addressed in the empirical analyses of this thesis.

Fourth, the empirical methodologies for model estimation are also reviewed. Two approaches: frequentist approach and Bayesian approach are reviewed and compared. The methods of imposing inequality conditions based on economic theory and the methods of model selections are also discussed in terms of frequency approach and Bayesian approach. The Markov Chain Monte Carlo (MCMC) method of integration and simulation is also illustrated and as one example of MCMC, Gibbs sampling is discussed. The state-space model is also reviewed and the Bayesian estimation of the state-space model by Gibbs sampler is presented, which provides the guidance of behavioural model estimation of this thesis.

Finally, based on the reviews of the existing literature, several issues are identified. The first one is that most of the analyses about BSE overlooks the impact of perceived risk on beef consumers' demand or producers' supply. The lack of consideration of risk perceptions is probably because the variable for risk perceptions is hard to obtain or the models are not easy to estimate with an unobservable variable such as risk perceptions. However, this rationale is not justified if the objective is to learn how BSE affected risk perceptions and how the BSE risk perceptions influenced beef demand and cattle supply. The second issue relates to the research on the evolution of the perceived risk of BSE over time. Sociology and psychology have provided certain theoretical frameworks such as the SARF to characterize the dynamic process of risk perception under the impacts of social and individual variables and to characterize how risk affects individuals, industries, government policies like a "rippling" effect. However, there are no studies in economics yet about how the BSE risk perceptions have evolved over time and how they affect the beef consumers, producers and the whole beef industry. The final issue is the problem of structural and technical changes within the beef and cattle sector model due to the BSE outbreak. These issues therefore, provide the initiatives for this thesis.

Chapter 3 Theoretical and Empirical Models

3.1 Introduction

The literature review about expected utility and risk perceptions provides the basis for constructing a theoretical model of individual behaviour incorporating risk perceptions. In this chapter, theoretical and empirical models of Canadian consumers and cow-calf producers are developed and the predictive difference approach and the state-space approach are employed to identify changing risk perceptions related to BSE. Further, parametric and non-parametric structural break tests are discussed as another way to provide empirical guidance about how to test behavioural changes of Canadian consumers and cow-calf producers related to the BSE outbreak.

3.2 Consumer Demand Model under BSE Impacts

3.2.1 Theoretical and Empirical Models of Consumers' Behaviour under Risk

To incorporate risk into an individual's decision-making process, a theoretical model is required. Assume an individual has control variables X (such as meat demand by consumers) that may be random and their cumulative distribution F(X, B), where B is a parameter that represents the risk level of X (Rothschild and Stiglitz, 1971) and can be named as an index of Rothschild–Stiglitz risk (Menezes et al., 2005). As discussed by Rothschild and Stiglitz, an individual will choose an appropriate B to maximize his (her) expected utility[16]. Expected utility can be shown as:

$$EU = \int U(X)\, dF(X,B) \quad , \tag{3.1}$$

where U is the utility function, and E is an expectation operator. A maximization of the expected utility function is (Menezes et al., 2005):

$$Max\ EU = \int U(X)\, dF(X,B) \qquad s.t. \qquad PX = M \ , \tag{3.2}$$

[16] For example, an individual can select an optimal portfolio mix among a set of portfolios of risk assets to maximize the expected utility of terminal wealth.

where M is income and P is a vector of prices. The optimal solution for this maximization problem is: $X^* = X(P, M, B)$. The derived utility function or indirect expected utility function is (Dalal and Arshanapalli, 1993; Menezes et al., 2005):

$$V = V(P, M, B). \tag{3.3}$$

Traditional Roy's Identity is still effective by the envelope theorem. So the optimal demand for X can be derived as:

$$X^* = X(P, M, B) = -\frac{dV}{dP} / \frac{dV}{dM}. \tag{3.4}$$

The difference between the demand function under risk and the demand function under certainty is that the risk parameter B is incorporated into the demand function. The derivative of the indirect utility function $V = V(P, M, B)$ with respect to B is a measure of disutility related to the risk (Menezes et al., 2005). Because B is an optimal risk parameter selected by the individual, it may be used to represent the levels of risk perceptions held by the individual. Based on the comparative statics from Menezes et al. (2005), consumer demand should decrease if the risk level (B) is increased. There are two problems not solved yet. First, B may not be constant over time because risk perceptions of people may be evolving over time. The demand function with risk parameter B evolving over time can be specified as:

$$X_t^* = X(P_t, M_t, B_t). \tag{3.5}$$

It is assumed that there is more than one good included in X but the risk is only associated with the consumption of good i. An expenditure share equation for good i can be derived as:

$$W_{i,t}^* = P_{i,t} X_{i,t}^* / M_t = W_i(P_t, M_t, B_t), \tag{3.6}$$

where $W_{i,t}$ is the optimal expenditure share for good i at time t. Second, B_t is not observable and must be estimated through different methods. Given the pros and cons of different methods used to measure risk perceptions as reviewed in Chapter 2 and data availability, the predictive difference approach and the state-space approach can be applied.

Because the focus of this research is on the analyses of the risk from BSE, B is defined as the perceived risk associated with BSE affecting the distribution of beef demand. Assuming the baseline risk perception B_0 is invariant before a risky event occurs at time t1 and is additively separable from W, a simplest expression of behaviour before the risky event incorporated with baseline risk perceptions may be written as:

$$W_{i,t} = W(P_t, M_t, \alpha 1) - B_0, \qquad t \in (1, \dots t1), \tag{3.7}$$

where $\alpha 1$ is a vector of parameters. A simplest expression of behaviour after the risky event incorporated with current risk perceptions may be written as:

$$W_{i,t} = W(P_t, M_t, \alpha 2) - B_t, \qquad t \in (t1+1, \dots T). \tag{3.8}$$

Further, a combined expression of behaviour for the entire period (including both the periods prior to and after the risk event) incorporated with current and baseline risk perceptions may be written as:

$$W_{i,t} = W(P_t, M_t, \alpha 3) - B_0 - I(t > t1) * (B_t - B_0)\ ,\ t \in (1, \dots t1, .. T) \tag{3.9}$$

where $\alpha 2, \alpha 3$ are vectors of parameters and $\alpha 3$=($\alpha 1$+ $I(t > t1) * \delta)$. I is a dummy variable which is equal to 1 when t>t1 and zero otherwise. $\delta = \alpha 2 - \alpha 1$. If there are no structural changes at time t1 in the slope parameters, δ should not be statistically different from zero. The baseline risk perceptions B_0 and the risk perceptions after the risky event B_t are not observable. The predictive difference approach makes use of the difference between two predictions (one based on the pre-risky-event period and the other based on the post-risky-event period) from a demand model to approximate risk perception deviations from the benchmark risk perception before the risky event. If there are no impacts from the risky event and no other structural changes, the two predictions should be the same. Because the structural changes from factors other than risk perceptions are already incorporated in the model estimation, the difference between these two predictions can reflect the impacts of risky events and can be used as an index of individual risk perception changes after the risky event. Assuming the predictions for the post-risky-event period based on equation 3.7, 3.8 and 3.9 are

$$\widehat{W}_{i,t} = W(P_t, M_t, \hat{\alpha} 1),\ \widehat{\widehat{W}}_{i,t} = W(P_t, M_t, \hat{\alpha} 2),\ \widehat{\widehat{\widehat{W}}}_{i,t} = W(P_t, M_t, \hat{\alpha} 3),$$
$$t \in (t1+1, \dots T)\ . \tag{3.10}$$

The risk perception deviations for the post-risky-event period may be approximated by predictive differences as[17]:

$$Pd_t = \left(W_{i,t} - \hat{\hat{W}}_{i,t}\right) - \left(W_{i,t} - \hat{W}_{i,t}\right) = \hat{W}_{i,t} - \hat{\hat{W}}_{i,t}$$
$$= W(P_t, M_t, \hat{\alpha}1) - W(P_t, M_t, \hat{\alpha}2)$$
$$= \left(\hat{B}_t - \hat{B}_0\right) + \varepsilon_t$$
$$= devPOR_t + \varepsilon_t \quad , \qquad t \in (t1+1, \ldots T) \quad , \qquad (3.11)$$

where $devPOR_t$ is defined as deviations of risk perceptions that can be affected by different information indices as well as other things about the risky events. ε_t is a random error. The SARF and PRT can then be applied to evaluate the impacts of BSE media information on the risk perception deviations, which will be explored in the next section of this chapter. When there are insufficient observations in the second sample (sample for $t \in (t1+1, \ldots T)$), it is impossible to estimate the equation 3.8 and the prediction from equation 3.9 for the post-risky-event period is used instead and the risk perception deviations for the post-risky-event period may be approximated by predictive differences as:

$$Pd_t = \left(W_{i,t} - \hat{\hat{\hat{W}}}_{i,t}\right) - \left(W_{i,t} - \hat{W}_{i,t}\right) = \hat{W}_{i,t} - \hat{\hat{\hat{W}}}_{i,t}$$
$$= W(P_t, M_t, \hat{\alpha}1) - W(P_t, M_t, \hat{\alpha}3)$$
$$= \left(\hat{B}_t - \hat{B}_0\right) + \varepsilon_t$$
$$= devPOR_t + \varepsilon_t \quad , \qquad t \in (t1+1, \ldots T) \ . \qquad (3.12)$$

The state-space approach, on the other hand, provides an estimate of the risk perception parameters B_t directly. Although B_t is unobservable, its dynamic or evolution pattern can be constructed by SARF and PRT as:

$$B_t = a * B_{t-1} + \beta * f(Z_t) + \varphi_t \qquad (3.13)$$

where Z_t is a vector of variables affecting risk perceptions including information about the risky event, time, etc. Equations 3.6 and 3.13 can form a linear or non-linear state-space model and can be estimated through a Bayesian method. Given the theoretical model of optimal demand under risk, the empirical functional form

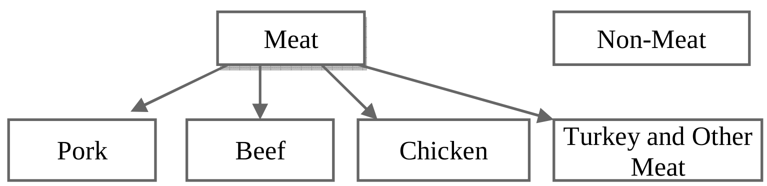
[17] The risk perception deviations are approximated by the prediction of expenditure shares based on pre-BSE period minus that based on post-BSE period because consumers may react to an increasing risk perception by decreasing their consumption of the risky good.

needs to be developed. Because the demand function under risk derived from the indirect utility function is similar to the traditional demand function with the exception of the risk parameter, econometric tests can be used to select appropriate functional forms.

It should be noted that the approach to incorporating media information about BSE into the demand model is different from those in the existing literature. First, both the predictive difference approach and the state-space approach are used to estimate the risk perceptions about BSE and the impacts of various media information on risk perceptions about BSE, providing empirical measures about how people adjust their risk perceptions after receiving different information and how their risk perceptions affect their market behaviour. In contrast, traditional approaches to incorporating media information directly into the demand model fail to recognize the relationship among information, consumer risk perceptions and market behaviour and fail to characterize the evolution path of consumer risk perceptions. Secondly, different information indices are constructed in this study to reflect both the quantitative and qualitative aspects of media information about BSE including gross media information indices, subject media information indices and source credibility information index. It should be noted that the subjects addressed in the media information and the sources of media information are used to represent the qualitative aspects of media information. These information to some extent, reflect media framing methods (Petty and Cacioppo, 1984; Renn and Levine, 1991; Priester and Petty, 1995; Frewer et al., 1998; 1999; Frewer, 2003). In the traditional approaches, only gross media information indices about BSE are usually incorporated.

Traditional demand theory is based on the assumption that consumers are maximizing their utilities given their budgets. The demand for a certain good or service is derived from the utility maximization problem. In reality, consumers always face a large list of goods or services to purchase such as clothes, shoes, meats, drinks, electricity, housing, restaurant, etc. A complete demand system including all these goods or services may be impossible to estimate. However, if these goods or services can be grouped into subsets, the demand analysis will be much more simple. One important assumption for grouping of goods is weak separability where the marginal rates of substitution among the goods inside the group will not be dependent on any goods outside of the group (Green, 1976; Deaton and Muellbauer, 1980b). Given weak separability, beef consumers can be assumed to first allocate their expenditure to broad groups of goods including meat and non-meat and then allocate the expenditure of meat to different types of meats. The empirical restrictions over which weak separability is satisfied are that the intergroup Slutsky substitution terms are proportional to the corresponding income effects of the goods in question (Goldman and Uzawa, 1964). One graphic illustration of this two-stage demand system in meat consumption is:

Figure 3.1 Utility Trees



The first stage of the demand system is sometimes specified as a Log-Linear form (Heien and Wessells, 1988) , as a doublelog form (Goddard et al., 2004; Lomeli, 2005), as a linear expenditure function (Fan et al., 1995; Richards et al., 1997) or as other flexible functional forms (Gao et al., 1996; Michalek and Keyzer, 1992) and the second stage as some flexible functional form such as TransLog (Christensen and Manser, 1977), Almost Ideal Demand System (Deaton and Muellbauer, 1980a), Generalized Leontief System (Diewert, 1971). For simplicity, the doublelog-TransLog (first stage-doublelog and second stage-TransLog) demand system is selected for the empirical analysis in this chapter. The specifications, properties and associated elasticities of the doublelog-TransLog demand system are discussed in Appendix D.

Beyond the incorporation of the risk parameter into the model and the selection of an appropriate functional form, the data are also crucial for estimation. Different econometric techniques are required for time series data and panel data. In the following sections, consumer demand models based on different types of data are discussed.

3.2.2 Consumer Demand Model with Predictive Difference Approach and Time Series Data

Based on the derivations in the previous section and considering the impacts of other variables on consumer demand, a flowchart for model construction and risk perception estimation by the predictive difference approach is shown in Figure 3.2.

Figure 3.2 Demand Model and Risk Perception Estimation by Predictive Difference Approach and Time Series Data

First stage of demand system:

$$LnTEXP_t = a_0 + \sum_{i=1}^{3} a_i * Seasonal\ dummy_i + a_4 * \sum_{i=1}^{4} w_{i,t} * LnP_{i,t} + a_5 * PDI_t + a_6 * LnTEXP_{t-1}$$

Second stage of demand system:

$$w_{i,t} = \frac{b_{i,0} + \sum_{i=1}^{3} b_{i,j} * Seasonal\ dummy_i + \sum_{j=1}^{4} c_{i,j} * LnP_{j,t} + d_i * LnTEXP_t + e_i * LnQ_{i,t-1} + f_i * t}{\sum_{j=1}^{4} b_{i,0} + \sum_{i=1}^{4}\sum_{j=1}^{3} b_{i,j} * Seasonal\ dummy_j + \sum_{i=1}^{4}\sum_{j=1}^{4} c_{i,j} * LnP_{j,t} + \sum_{i=1}^{4} d_i * LnTEXP_t + \sum_{i=1}^{4} e_i * LnQ_{i,t-1} + \sum_{i=1}^{4} f_i * t} + \varepsilon_{i,t}$$

Equation system $\begin{cases} LnTEXP \\ w_i \end{cases}$ is estimated based on the data before the BSE outbreak in Canada in the second quarter of 2003(1st quarter, 1978-1st quarter, 2003). Based on the parameters estimated, predictions of $\begin{cases} LnTEXP_{i,t} \\ W_{i,t} \end{cases}$, after the BSE outbreak in Canada in the 2nd quarter of 2003 are obtained and named as: : $\begin{cases} \widehat{LnTEXP}_{i,t} \\ \widehat{W}_{i,t} \end{cases}$,

Equation system $\begin{cases} LnTEXP \\ w_i \end{cases}$ is estimated based on the data of the entire whole sample (1st quarter, 1978-4th quarter, 2005)[a]. Based on the parameters estimated, predictions of $\begin{cases} LnTEXP_{i,t} \\ W_{i,t} \end{cases}$, after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $\begin{cases} \hat{\hat{\widehat{LnTEXP}}}_{i,t} \\ \hat{\hat{\widehat{W}}}_{i,t} \end{cases}$,

$$Pd_{beef,t} = \widehat{W}_{i,t} - \hat{\hat{\widehat{W}}}_{i,t}$$

$$Pd_{beef,t} = devPOR_t + \varepsilon_t = -B_0 * (1-\alpha) + \alpha * devPOR_{t-1} + \beta * f_t(Media_t) + \varepsilon_t$$

$$Pd_{beef,t} = -B_0 * (1-\alpha) + \alpha * Pd_{beef,t-1} + \beta * (k_1 * \text{Gross Media Coverage of BSE}_t + k_2 \text{'Source Credibility Media indices of BSE}_t + k_3 \text{'Media Subject Indices of BSE}_t + k_4 * T) + \varepsilon_t - \alpha * \varepsilon_{t-1}$$

where $\alpha + \beta = 1$.

a: The model is estimated for the entire period given the insufficient observations for post-BSE period to estimating a demand model. Structural changes of the equation system after BSE outbreak will be tested in advance and if there are structural changes, the model will be estimated by incorporating the dummies of each quarter for the post-BSE period.

where $LnTEXP_t$ is the logged total meat expenditure at t, Seasonal dummy$_i$ is the quarterly dummies (i=1,2,3), $w_{i,t}$ is the expenditure share of meat i in total meat expenditure at t, $LnP_{i,t}$ is the logged price of meat i at t, PDI_t is the per capital disposable income at t, t is time trend variable, $Q_{i,t-1}$ is quantity of disappearance of meat i at t-1, $\mathrm{Pd}_{\mathrm{beef},\,t}$ is predictive difference at time t, $devPOR_t$ is risk perception deviation at t, B_0 is the baseline risk, $Media_i$ are media indices about BSE, $\varepsilon_{0,t}, \varepsilon_{i,t}, \varepsilon_t$ are random errors, and $a_i, b_{i,j}, c_{i,j}, d_i, e_i, f_i, \alpha, \beta, k_i$ are parameters to be estimated. Seasonal and time trend variables are included in the demand system to capture seasonality and trends in meat consumption. The lagged disappearance of meat i and the lagged total meat expenditure per capita are used to capture habit formation on consumer purchases.

As shown in Figure 3.2, two-stage demand system is estimated over two time periods. The first is from time 1 to T_B, where T_B is the point in time in this research when the BSE-infected cow was found in Canada in May, 2003. The other is estimated from the entire period available. Two predictions can be made for the time period after the BSE-infected cow was found in Canada at May, 2003. Based on the data from time 1 to T_B, the two-stage demand system is estimated and used to generate the first predictions of total meat expenditure and meat expenditure shares for the time period after BSE-infected cow was found. Based on the data from the entire time period, the two-stage demand system is estimated and used to generate the second predictions of total meat expenditure and meat expenditure shares for the time after BSE-infected cow was found. The difference in the beef expenditure shares from the two predictions is estimated to be a proxy for risk perception deviations due to BSE and a random error term as:

$$\mathrm{Pd}_{\mathrm{beef},t} = w_{beef}hat_{1,t} - w_{beef}hat_{2,t} \quad (3.14)$$

$$\mathrm{Pd}_{\mathrm{beef},\,t} = devPOR_t + \varepsilon_t,\ t=T_B+1,...,T. \quad (3.15)$$

The use of predictive differences to approximate BSE risk perception changes can decrease the error caused by taking the difference between the predicted variable and the real variables as reviewed in Chapter 2 (section 2.2.5.1.1). Also, the impacts of variables other than BSE risk perception deviations in the predictive differences are accounted for by the stochastic error term. However, the predictive differences after BSE outbreak may still include the impacts from other factors or omitted variables such as the concerns about other food borne diseases for consumers. Therefore, the predictive differences estimated are actually an upper bound of the risk perceptions about BSE due to not controlling the excluded or omitted variables. The risk perception deviations are constructed following the equation 2.11 in Chapter 2 and equation 3.11 in this chapter based on SARF and PRT. The gross media coverage is included in the risk perception equations. However, the information indices about articles' attitudes such as $N\inf_{t-k}$ and $P\inf_{t-j}$ are not included. This is because that it is subjective to judge the tones of BSE-related articles, that there is a high correlation between the negative-attitude media index and the gross media index about BSE, and that it is suggested by the quantity coverage theory that regardless the attitudes of news articles, the gross media coverage acts as an amplifier for risk perceptions (Smith et al., 1988; Rowe et al., 2000; Lobb, 2005). Two types of media quality indices including national media index and media subject indices (Gerbner, 1985) are incorporated instead. The construction of these media indices are discussed in the data section of the consumer model chapter (section 4.2.1). The risk perception equation is:

$$POR_t = \alpha_t * POR_{t-1} + \beta * f_t(\text{Gross Media Coverage for BSE}_t, \text{National media index for BSE}_t, \text{Media Subject Indices for BSE}_t, T) \quad , \qquad (3.16)$$

where POR_t is the posterior or current risk perception at t. By subtracting the baseline risk B_0 from both sides of 3.16 and rearranging the terms within the risk perception equation, the risk perception change is represented as:

$$devPOR_t = -B_0 * (1-\alpha) + \alpha * devPOR_{t-1} + \beta * f_t(\text{Gross Media Coverage for BSE}_t, \text{National media index for BSE}_t, \text{Media Subject Indices for BSE}_t, T), \qquad (3.17)$$

where $devPOR_t$ is the deviation of the posterior risk perception at t from the average baseline risk perception B_0. Taking the first order Taylor expansion of f_t, equation 3.17 is converted to:

$$devPOR_t = -B_0 * (1-\alpha) + \alpha * devPOR_{t-1} + \beta * (l_1 * \text{Gross Media Coverage for BSE}_t + l_2 * \text{National media index for BSE}_t + l_3' \text{Media Subject Indices for BSE}_t + l_4 * T) \quad (3.18)$$

The media subject indices of BSE include BSE information addressing government, scientists, producers and BSE affected producers. By substituting the BSE risk perception deviation $devPOR_t$ into equation 3.15, the final estimated equation is as follows:

$$\text{Pd}_{\text{beef,t}} = -B_0 * (1-\alpha) + \alpha * \text{Pd}_{\text{beef,t-1}} + \beta * (l_1 * \text{Gross Media Coverage for BSE}_t + l_2 * \text{National media index for BSE}_t + l_3' \text{Media Subject Indices for BSE}_t + l_4 * T) + \varepsilon_t - \alpha * \varepsilon_{t-1}, \quad (3.19)$$

where $\alpha + \beta = 1$. In the final form of the risk perception equation, the BSE media index addressing producers is removed due to its high collinearity with the BSE media index addressing BSE affected producers (condition number =139>30). Multicollinearity is evaluated by a condition number among variables X (Belsley et al., 2004). The condition number is a square root of ratio of largest to smallest eigenvalues of the characteristic matrix of X'X. Usually, if the condition number is larger than 30, there is a serious collinearity among variables X while if the condition number is larger than 100, there is a severe collinearity.

The predicted risk perception measures can be computed through:

$$\hat{POR}_t = \hat{\alpha} * \hat{POR}_{t-1} + \hat{\beta} * (\hat{l}_1 * \text{Gross Media Coverage of BSE}_t + \hat{l}_2 * \text{National media index of BSE}_t + \hat{l}_3' \text{Media Subject Indices of BSE}_t + \hat{l}_4 * T), \quad (3.20)$$

where $\hat{POR}_0 = \hat{B}_0; \hat{\alpha}, \hat{\beta}, \hat{l}_1$ are estimated parameters. By defining the differences in pork, chicken, turkey expenditure shares from the two predictions in the same manner as beef and regressing them with the predicted risk perceptions about BSE, we can find the impacts of BSE risk perception on these related meats. The equations are as follows:

$$Pd_{i,t} = g_{j,0} + g_{j,1} * \hat{POR}_t + \eta_{j,t} \quad , \quad (3.21)$$

where t=T_B+1, …T, j=pork, chicken, turkey or total meat expenditure, $Pd_{i,t}$ is the predictive differences in pork, chicken and turkey expenditure shares or total meat expenditure, $g_{j,0}$ and $g_{j,1}$ are parameters to be estimated, and $\eta_{j,t}$ is the random error. It is worth noting that the impacts of other variables in predictive difference $Pd_{i,t}$ are included in $g_{j,0}$ or error term $\eta_{j,t}$.

Because the risk perceptions about BSE are approximated as the differences between two predictions of beef expenditure shares, the elasticity of beef demand with respect to BSE risk perception can be computed by:

$$\varepsilon_{beef,R} = -\overline{\hat{POR}} \Big/ \overline{\hat{w}_{beef}} \quad , \tag{3.22}$$

where $\varepsilon_{beef,R}$ is the risk perception elasticity for beef, $\overline{\hat{POR}}$ is the mean of predicted BSE risk perceptions and $\overline{\hat{w}_{beef}}$ is the mean predicted beef expenditure share based on the time series model for the entire time periods (including periods before and after BSE). The elasticity of other meat demand with respect to BSE risk perception can be computed as:

$$\varepsilon_{j,R} = -g_{j,1} * \overline{\hat{POR}} \Big/ \overline{\hat{w}_j} \quad , \tag{3.23}$$

where j=pork, chicken, turkey; $\varepsilon_{j,R}$ is the risk perception elasticity of pork (chicken or turkey), and $\overline{\hat{w}_j}$ is the mean of predicted expenditure shares of pork (chicken or turkey).

3.2.3 Consumer Demand Model with Predictive Difference Approach and Panel Data

Similar to time series data, a two-stage demand system can be defined with the first stage as a total meat expenditure function and the second stage as expenditure share functions for different meats including beef, pork, chicken, turkey and seafood. Different from the time series demand model, the model based on household panel data incorporates demographic variables from different households. The empirical form of the demand system is similar to the models used for the time series data. The first stage of the demand system is a doublelog function while the second stage is share equations derived from a TransLog indirect utility function. The flowchart for model construction and risk perception estimation by the predictive difference approach is shown in Figure 3.3.

Figure 3.3 Demand Model and Risk Perception Estimation using the Predictive Difference Approach and Panel Data

Single-index individual-specific effect: $a_{0,k} = a_0 + \sum_{k=1}^{K} \xi_k * Demo_k ; b_{i,k,0} = b_{i,0} + \sum_{k=1}^{K} \zeta_{i,k} * Demo_k$

First stage of demand system:

$$LnTEXP_{k,t} = a_{0,k} + \sum_{i=1}^{3} a_i * Seasonal\ dummy_i + a_4 * \sum_{i=1}^{4} w_{i,k,t} * LnP_{i,k,t} + a_5 * PDI_{k,t}$$
$$+ a_6 * LnTEXP_{k,t-1} + \varepsilon_{0,k,t}$$

Second stage of demand system:

$$w_{i,k,t} = \frac{b_{i,k,0} + \sum_{i=1}^{3} b_{i,j} * Seasonal\ dummy_i + \sum_{j=1}^{4} c_{i,j} * LnP_{j,k,t} + d_i * LnTEXP_{k,t} + e_i * LnQ_{i,k,t-1}}{\sum_{j=1}^{4} b_{i,k,0} + \sum_{i=1}^{4} \sum_{j=1}^{3} b_{i,j} * Seasonal\ dummy_j + \sum_{i=1}^{4} \sum_{j=1}^{4} c_{i,j} * LnP_{j,k,t} + \sum_{i=1}^{4} d_i * LnTEXP_{k,t} + \sum_{i=1}^{4} e_i * LnQ_{i,k,t-1}} + \varepsilon_{i.k.t}$$

Equation system $\begin{cases} LnTEXP \\ w_i \end{cases}$ is estimated based on the data before BSE outbreak in Canada in 2003 (2002-2003). Based on the parameters estimated, the predictions of $\begin{cases} LnTEXP_{i,k,t} \\ W_{i,k,t} \end{cases}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $\begin{cases} \widehat{LnTEXP}_{i,k,t} \\ \widehat{W}_{i,k,t} \end{cases}$

Equation system $\begin{cases} LnTEXP \\ w_i \end{cases}$ is estimated based on the data after BSE outbreak in 2003 (2004-2007). Based on the parameters estimated, the predictions of $\begin{cases} LnTEXP_{i,k,t} \\ W_{i,k,t} \end{cases}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $\begin{cases} \widehat{\widehat{LnTEXP}}_{i,k,t} \\ \widehat{\widehat{W}}_{i,k,t} \end{cases}$

$$Pd_{beef,t} = \widehat{W}_{i\ t} - \widehat{\widehat{W}}_{i\ t}$$

$$\mathrm{Pd}_{\mathrm{beef},k,\mathrm{t}} = devPOR_{k,t} + \varepsilon_{k,t} = -A_{0,i} * (1-\alpha) + \alpha * devPOR_{k,t-1} + \beta * f_t(Media_{k,t}) + \varepsilon_{k,t}$$

$$\mathrm{Pd}_{\mathrm{beef},k,\mathrm{t}} = -A_{0,i} * (1-\alpha) + \alpha * \mathrm{Pd}_{\mathrm{beef},k,\mathrm{t-1}} + \beta * (k_1 * \text{Gross Media Coverage of BSE}_{k,\mathrm{t}}$$
$$+ k_2 \text{'Source Credibilit y Media indices of BSE}_{k,\mathrm{t}} + k_3 \text{'Media Subject Indices of BSE}_{k,\mathrm{t}}$$
$$+ k_4 * T) + \varepsilon_{k,t} - \alpha * \varepsilon_{k,t-1}$$

where: $\alpha + \beta = 1$, $LnTEXP_{k,t}$ is the logged total meat expenditure of individual k at t, $quarter_i$ is the quarterly dummies (i=1,2,3), $w_{i,k,t}$ is the expenditure share of meat i in total meat expenditure of individual k at t, $LnP_{i,k,t}$ is the logged price of meat i of individual k at t, $PDI_{k,t}$ is the per capital disposable income of individual k at t, t is time trend variable, $Q_{i,k,t-1}$ is quantity of disappearance of meat i of individual k at t-1, $\mathrm{Pd}_{\mathrm{beef},k,\mathrm{t}}$ is predictive difference of individual k at time t, $devPOR_{k,t}$ is risk perception deviation of individual k at t, A_0 is the baseline risk, $Media_{k,i}$ are media indices about BSE of individual k, $\varepsilon_{0,k,t}, \varepsilon_{i,k,t}, \varepsilon_{k,t}$ are random errors, and $a_i, b_{i,j}, c_{i,j}, d_i, e_i, f_i, \alpha, \beta, k_i, \xi_i, \zeta_{i,j}$ are parameters to be estimated. The seasonal variables are included in the demand system to capture seasonality. The time trend variable is not included due to a high multicollinearity (condition number=171>30) with other variables. Lagged disappearance of meat i and the lagged total meat expenditure are used to capture habit formation.

It should be noticed that the demand system in Figure 3.3 is for each household in the sample. Therefore, a panel data nonlinear demand system is estimated. As reviewed by Cameron and Trivedi (2005, page 780), the individual effects can be incorporated into the non-linear panel data model through additive, multiplicative and single-index individual-specific effect specifications. The individual-specific effect can be defined as a_i, other variables and their parameters as x_i and β, where x_i includes the demand system variables in the first and second stage of the demand system. The demographic specifications from Cameron and Trivedi (2005, page 780) are as follows:

Additive: $f(a_i,x_i, \beta)=a_i+f(x_i, \beta)$; Multiplicative: $f(a_i,x_i, \beta)=a_i*f(x_i, \beta)$

Single-index individual-specific effect: $f(a_i,x_i, \beta)=f(a_i +x_i\beta)$. (3.24)

The single-index individual-specific effect approach is selected for model specification in Figure 3.3. The individual effect a_i is augmented as a function of demographic variables of individuals and a common constant. Similar to the demand model based on time series data, the two-stage demand system is estimated and two required predictions are generated. Differences in the beef expenditure shares from the two predictions are then used to be a function of risk perception deviations due to BSE and a random error term. The final risk perception equation and the associated elasticities for estimation are similar to the ones in the time series model (equation 3.18-3.23). However, because we are using the household level data, the initial risk perception may be different across households and therefore, the intercept of the risk perception equations should be household specific[18].

[18] Subject to model convergence, it is impossible to modify the intercepts within the risk perception equations as a function of all of the household demographic variables. The final intercepts specified in risk perception equations are varying across different regions.

3.2.4 Consumer Demand Model with State-Space Approach

Another way to track risk perceptions through demand models is through a linear or nonlinear state-space approach[19]. As reviewed in the consumer risk perception section and based on equation 3.6 and 3.13, the state-space demand model incorporating risk perceptions about BSE can be specified as illustrated in Figure 3.4.

The variable definitions in the state-space model are the same as those in the predictive difference approach. The only difference relates to the estimated risk perception. In the predictive difference approach, the risk perception deviation is approximated while in the state-space approach, the risk perception itself is estimated directly. Also, the specification of the risk perception equation is somewhat different from that of the predictive difference approach by reducing the parameters β, k_j, α within the original risk perception equation (3.13) to $r_j = \beta * k_j / \alpha$ and restricting the sum of the r_j's as zero, where k is a parameter vector in function f(Z). This constraint is based on the fact that the number of messages about BSE risk is small and all media indices can be set to 1 in the initial period, and also based on the hypothesis that the risk perceptions before BSE outbreak are very small and can be set to zero. This reduction of parameters is necessary for an identification of both parameters within the demand model and within the risk perception equation.

The selection of priors for the Bayesian state-space model is based on the parameters estimated through the predictive difference approach with the hypothesis that both approaches should produce similar results. The economic property tests implied by the indirect utility functions such as symmetry and zero homogeneity are imposed on demand system and maintained due to the high multicollinearity (condition number=170>30) and identification issues of the demand system without these properties. Homothetic separability is also imposed for the requirement of price and quantity aggregation in a two-stage demand system (Green, 1976).

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[19] A panel data state-space model for consumers or farmers is also estimated but failed in convergence.

Figure 3.4 Demand Model and Risk Perception Estimation by State-Space Approach and Time Series Data

First stage of demand system:

$$LnTEXP_t = a_0 + \sum_{i=1}^{3} a_i * Seasonal\ dummy_i + a_4 * \sum_{i=1}^{4} w_{i,t} * LnP_{i,t} + a_5 * PDI_t + a_6 * LnTEXP_{t-1} + a_7 * t + a_8 * B_t + \varepsilon_{0,t}$$

Second stage of demand system:

$$w_{i,t} = \frac{b_{i,0} + \sum_{i=1}^{3} b_{i,j} * Seasonal\ dummy_i + \sum_{j=1}^{4} c_{i,j} * LnP_{j,t} + d_i * LnTEXP_t + e_i * LnQ_{i,t-1} + f_i * t + h_i * B_t}{\sum_{j=1}^{4} b_{i,0} + \sum_{i=1}^{4}\sum_{j=1}^{3} b_{i,j} * Seasonal\ dummy_j + \sum_{i=1}^{4}\sum_{j=1}^{4} c_{i,j} * LnP_{j,t} + \sum_{i=1}^{4} d_i * LnTEXP_t + \sum_{i=1}^{4} e_i * LnQ_{i,t-1} + \sum_{i=1}^{4} h_i * B_t} + \varepsilon_{i,t}$$

Risk perception equation:

$B_t = \alpha * B_{t-1} + \beta * f_t$(Gross Media Coverage for BSE $_t$, National media index for BSE $_t$, Media Subject Indices for BSE $_t$, T) $\Rightarrow$

$B_t = \alpha * B_{t-1} + \beta * (l_1 *$ Gross Media Coverage for BSE $_t$ $+ l_2 *$ National media index for BSE $_t + l_3$' Media Subject Indices for BSE $_t + l_4 * T$) $\Rightarrow$

$B_t' = B_{t-1}' + r_1 *$ Gross Media Coverage of BSE $_t + r_2 *$ National Media index of BSE $_t$ $+ r_3$' Media Subject Indices of BSE $_t + r_4 * T + \varphi_t$

where φ_t is a random error, $r_j = \beta * l_j / \alpha$, $B_t' = B_t / a$. The risk perception formation in the state-space model is somewhat different from that of the predictive difference approach due to the identification requirement for estimation. An additional constraint $\sum_j r_j = 0$ is also imposed based on the assumption that the initial risk perception (B_0) is zero and initial information indices all normalized to 1. Although the imposition of this restriction is arbitrary, it guarantees the identification of parameters in both demand and risk perception equations.

State-space form:

$Y_t = F_t(A, X_t, \theta, B_t) + E_t$;

$B_t = B_{t-1} + J * z_t + \varphi_t$

where:

$Y_t = (LnTEXP_t\ ,\ w_{beef,t}\ ,\ w_{pork,t}\ ,\ w_{chicken,t})^T$;

$X_t = (LnTEXP_t, \sum_{i=1}^{K} w_i * LnP_i, constant,\ LnTEXP_{t-1}, Quarter_{1,t}, Quarter_{2,t}, Quarter_{3,t}, LnP_{beef,t}, LnP_{pork,t}, LnP_{chicken,t}, LnP_{turkey,t}, LnQ_{beef,t-1}, LnQ_{pork,t-1}, LnQ_{chicken,t-1}, LnQ_{turkey,t-1}, PDI_t, t)^T$;

$A = (a_0, a_1, ..., a_7, b_{beef,0}, b_{beef,1}, b_{beef,2}, b_{beef,3}, c_{beef,beef}, c_{beef,pork}, c_{beef,chicken}, c_{beef,turkey}, c_{pork,pork}, c_{pork,chicken}, c_{pork,turkey}, c_{chicken,chicken}, c_{chicken,turkey}, c_{turkey,turkey}, d_1, d_2, d_3, d_4, e_1, e_2, e_3, e_4, f_1, f_2, f_3, f_4)^T$;

$\theta = (a_8, h_1, h_2, h_3, h_4)^T$;

z_t = (Gross Media Coverage of BSE $_t$, National Media index of BSE $_t$, Media Subject Indices of BSE $_t$, T);

$J = (r_1, r_2, ... r_4)$; $E_t = (\varepsilon_0, \varepsilon_1, .. \varepsilon_4)$; $\Gamma_t = \varphi_t$ and $E_t \sim N(0, \Omega), \Gamma_t \sim N(0, \sigma^2)$

State-space model estimation by Bayesian methods

Conditional Density function (Geweke and Tanizaki, 2001)

Define $B_T = \{B_0, B_1, ... B_t\}$, $Y_T = \{y_1, y_2, ... y_t\}$, $X_T = \{x_1, x_2, ... x_t\}$, $Z_T = \{z_1, z_2, ... z_t\}$.

$P(B_T, Y_T \mid Z_T, X_T, \omega, A, J, \theta, \Omega, \sigma^2)$, $P(B_T \mid Z_T, \omega, J, \sigma^2)$, $P(Y_T \mid B_T, \theta, X_T, A, \Omega)$ represent respectively the conditional density of B_T, Y_T given $Z_T, X_T, \omega, B, J, \theta$, the conditional density of B_T given Z_T, ω, J , and the conditional density of Y_T given B_T, θ, X_T, A . we have:

$$P(B_T, Y_T \mid Z_T, X_T, \omega, A, J, \theta, \Omega, \sigma^2) = P(B_T \mid Z_T, \omega, J, \sigma^2) P(Y_T \mid B_T, \theta, X_T, A, \Omega)$$

Given a constant initial risk perception B_0 ,

$$P(B_T \mid Z_T, \omega, J, \sigma^2) = \prod_{t=1}^{T} P(B_t \mid B_{t-1}, Z_t, \omega, J, \sigma^2) , \quad P(Y_T \mid B_T, \theta, X_T, A, \Omega) = \prod_{t=1}^{T} P(y_t \mid B_t, \theta, X_t, A, \Omega)$$

By Bayesian theorem,

$$P(B_T \mid Y_T, X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2) = \frac{P(B_T, Y_T \mid X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2)}{\int P(B_T, Y_T \mid X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2) dB_T}$$

The parameters $B_T, A, \omega, J, \theta, \Omega, \sigma^2$ can be drawn directly from the conditional density function $P(B_T \mid Y_T, X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2)$, $P(A \mid B_T, \theta, Y_T, X_T, Z_T, \omega, J, \Omega, \sigma^2)$, $P(\omega \mid B_T, Y_T, X_T, A, Z_T, J, \theta, \Omega, \sigma^2)$, $P(J \mid B_T, Y_T, X_T, A, Z_T, \omega, \theta, \Omega, \sigma^2)$ and $P(\theta \mid B_T, Y_T, X_T, A, Z_T, \omega, J, \Omega, \sigma^2)$ through Metropolis-Hastings algorithm and Gibbs sampler. A random draw of B_T is realized through conditional density function:

$$\begin{aligned}
& P(B_T \mid B_0, B_1, ..., B_{t-1}, B_{t+1}, ... B_T, Y_T, X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2) \\
&= \frac{P(B_T \mid Y_T, X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2)}{\int P(B_T \mid Y_T, X_T, A, Z_T, \omega, J, \theta, \Omega, \sigma^2) dB_t} \\
&= \begin{cases} \dfrac{P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2) P(B_{t+1} \mid B_{t-1}, z_t, \omega, J, \sigma^2)}{\int P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2) P(B_{t+1} \mid B_{t-1}, z_t, \omega, J, \sigma^2) dB_t} & t = 1, 2, ... T-1 \\ \dfrac{P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2)}{\int P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2) dB_t} & t = T \end{cases} \\
&\propto \begin{cases} P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2) P(B_{t+1} \mid B_{t-1}, z_t, \omega, J, \sigma^2) & t = 1, 2, ... T-1 \\ P(y_t \mid x_t, A, B_t, \theta, \Omega) P(B_t \mid B_{t-1}, z_t, \omega, J, \sigma^2) & t = T \end{cases}
\end{aligned}$$

The posterior densities of $B, J, \omega, \theta, \Omega, \sigma^2$ are given by:

$$P(A \mid B_t, Y_T, X_T, Z_T, \omega, J, \theta, \Omega, \sigma^2) \propto P(Y_T \mid B_t, \theta, A, X_T, \Omega) P(B), \quad P(\theta \mid B_t, Y_T, X_T, Z_T, \omega, J, A, \Omega, \sigma^2) \propto P(Y_T \mid B_t, \theta, A, X_T \Omega) P(\theta)$$

$$P(\Omega \mid B_t, Y_T, X_T, Z_T, \omega, J, \theta, \sigma^2) \propto P(Y_T \mid B_t, \theta, A, X_T, \Omega) P(\Omega), \quad P(\omega \mid B_t, Y_T, X_T, Z_T, A, J, \theta, \Omega, \sigma^2) \propto P(B_t \mid Z_T, \omega, J, \sigma^2) P(\omega),$$

$$P(J \mid B_t, Y_T, X_T, Z_T, A, \omega, \theta, \Omega, \sigma^2) \propto P(B_t \mid Z_T, \omega, J, \sigma^2) P(J) \quad , \quad P(\sigma^2 \mid B_t, Y_T, X_T, Z_T, A, \omega, \theta, \Omega) \propto P(B_t \mid Z_T, \omega, J, \sigma^2) P(\sigma^2)$$

The elasticities associated with BSE can be estimated by:

Conditional elasticities:

$$CE_{i,RPBSE} = \overline{B} * (\frac{h_i}{wi} - (\sum h_i))/D\ , \tag{3.24}$$

Unconditional elasticities:

$$E_{i,RPBSE} = a_8 * \overline{B} + CE_{i,RPBSE}\ , \tag{3.25}$$

where i=beef, pork, chicken, turkey, $\overline{B}$ and $\overline{wi}$ are respectively the mean of risk perceptions about BSE and the mean of expenditure share of meat i. The h_i's are the parameters of BSE risk perceptions in the demand system. D is the denominator of the share equations. a_8 is the parameter of risk perception in the first stage meat expenditure equation.

3.2.5 Hypotheses to be Tested in Consumer Demand Model

The hypotheses to be tested in consumer demand model are as follows:

1. The Social Amplification of Risk Framework (SARF). SARF suggests that perceived risks are shaped by both the quantity and quality of media messages. This hypothesis is tested by examining the significance of estimated parameters on the gross information index about BSE and on the content information indices about BSE (including BSE information indices from national media) and subject indices about BSE (including BSE information addressing government, scientists, and BSE affected Canadian farmers).
2. Prospective Reference Theory (PRT). PRT suggests that people's ex poste risk perceptions are determined by their reference risk perceptions and sampled or stated risk perceptions (Viscusi, 1989). The reference risk perceptions can be represented by the ex poste risk perception in the previous time period. The sampled or stated risk perceptions can be represented by a function of information available and time (Liu et al., 1998). Under the predictive difference approach, if the parameter of the lagged predictive difference $Pd_{beef,t-1}$ is significant, the PRT is implied. Under the state-space approach, the parameter on lagged risk perceptions has been normalized to one and therefore, PRT is not testable.

3. Self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998). Self-adjustment of risk perceptions over time suggests that the dynamics of risk perception are related to time trends. It can be tested by the significance of parameters of time trend in risk perception equations.
4. “Sympathy” or “altruism” of Canadian consumers to the plight of Canadian cattle producers. This hypothesis can be tested by the parameter associated with BSE information addressing BSE affected producers.
5. Structural break tests at the time period when BSE media coverage was high in Canada and at the time period when domestic BSE was discovered in Canada. For quarterly time series data, structural breaks in the first quarter, 1994, the first quarter, 1996, the second quarter, 2003, the first quarter, and the first quarter, 2005 are tested. For the household panel, structural breaks in 2003, 2004, 2005 and 2006 for annual data and structural breaks in the first quarter, 2004 and first quarter, 2005 and the third quarter of 2006 for quarterly data are tested. Both the parametric and nonparametric tests can be applied to examining these possible structural breaks.
6. Seasonality, time trend and habit formation effects can be tested by the significance of parameters related to seasonal dummies, the time trend variable and the lagged meat disappearance variables.
7. The effects of demographic variables on consumer demand. These effects are tested by the significance of parameters related to various demographic variables.

3.3 Cow-Calf Producer Model under BSE Impacts

3.3.1 Theoretical and Empirical Models of Cow-calf Producers’ Behaviour under Risk

The theoretical model of producer decision-making under risk also needs to be specified before analyzing the behaviour of cow-calf producers. The profit function of producers is defined as π, the output and input prices are respectively

P and W, and the output and input quantities are respectively Y and X. The risk is assumed to come from the output prices in this case. The profit of producers is therefore defined as:

$$\pi = \mathrm{PY} - \mathrm{WX} \tag{3.26}$$

The expected utility of the profit of producers is:

$$\begin{aligned} \mathrm{E}U &= \int U(M^0 + \pi)\, dF(P,B) \\ &= \int U(M^0 + PY - WX)\, dF(P,B) \quad , \end{aligned} \tag{3.27}$$

where $U(.)$ is the utility function of the producer, E is expectation operator, M^0 is the initial wealth of the producer, F(P.B) is the distribution of output prices and B is the index of Rothschild–Stiglitz risk (Rothschild and Stiglitz, 1971; Menezes et al., 2005). An increase in B will lead to an increase in the risky level of P. Since the focus is on the analysis of the BSE impacts, B is defined as the risk level associated with BSE. In essence, if BSE risk increases, the risk level associated with the output prices for cow-calf producers is also increased. The price expectation and variance are $\overline{\mathrm{P}}$ and σ_{p}^2 respectively, where:

$$\overline{\mathrm{P}} = \int P\, dF(P,B)\ , \ \sigma_{\mathrm{p}}^2 = \int (P - \overline{\mathrm{P}})^2\, dF(P,B)\ . \tag{3.28}$$

Given a random variable $\mu \sim N(0,1)$, the random variable P can be expressed as:

$$\mathrm{P} = \overline{\mathrm{P}} + \sigma_{\mathrm{p}}\, \mu \tag{3.29}$$

The maximization of expected utility is:

$$\begin{aligned} &\mathrm{V}\big(\overline{\mathrm{P}}(\mathrm{B}), \sigma_{\mathrm{p}}^2(\mathrm{B}), \mathrm{W}, M^0\big) = \mathrm{Max}\ \mathrm{E}U \\ &= Max\ \int U(M^0 + PY - WX)\, dF(P,B) \\ &= Max\ \int U\big(M^0 + (\overline{\mathrm{P}} + \sigma_{\mathrm{p}}\, \mu)Y - WX\big)\, dF(\mu)\ , \end{aligned} \tag{3.30}$$

where V is the derived or indirect utility function. B is a chosen by producers to maximize their expected utility and therefore B may be used to represent the risk perceptions or subjective beliefs of producers. Applying the envelope theorem, the output supply and input demand equations can be derived as (Appelbaum and Ullah, 1997):

$$\begin{aligned} \mathrm{Y}^* &= \mathrm{Y}\big(\overline{\mathrm{P}}(\mathrm{B}), \sigma_{\mathrm{p}}^2(\mathrm{B}), \mathrm{W}, M^0\big) \\ &= \frac{d \int U\big(M^0 + (\overline{\mathrm{P}} + \sigma_{\mathrm{p}}\, \mu)Y - WX\big) dF(\mu)}{d\overline{\mathrm{P}}} \Big/ \frac{d \int U\big(M^0 + (\overline{\mathrm{P}} + \sigma_{\mathrm{p}}\, \mu)Y - WX\big) dF(\mu)}{dM^0} \end{aligned} \tag{3.31}$$

$$X^{*} = X\left(\overline{P}(B), \sigma_{p}^{2}(B), W, M^{0}\right)$$
$$= -\frac{d\int U\left(M^{0}+(\overline{P}+\sigma_{p}\,\mu)Y-WX\right)dF(\mu)}{dW} \bigg/ \frac{d\int U\left(M^{0}+(\overline{P}+\sigma_{p}\,\mu)Y-WX\right)dF(\mu)}{dM^{0}} \quad (3.32)$$

Similar to the theoretical model for consumers, the risk perception parameter B may be evolving over time and may not be observable through the market behaviour of producers. The predictive difference approach and state-space approach can be applied to estimate the relevant risk perception parameter B. The benchmark risk perception parameter before the risky event can be defined as B_0. The risk perception deviations may be approximated by predictive differences in outputs as[20]:

$$Pd_t = Y_t^{\ *} - Y_t^{\ **}$$
$$= Y\left(\overline{P}_t(B_t), \sigma_{p_t}^{2}(B_t), W_t, M^{0}\right) - Y\left(\overline{P_t}(B_0), \sigma_{p_t}^{2}(B_0), W_t, M^{0}\right)$$
$$= devPOR_t + \varepsilon_t\ , \quad (3.33)$$

where $Y_t^{\ *}$ is the prediction of Y_t based on the post-risky-event sample or the entire sample and $Y_t^{\ **}$the prediction of Y_t based on the sample before the risky event. $devPOR_t$ is defined as deviations in risk perceptions that are affected by different information indices about the risky events and ε_t is a random error. SARF and PRT can then be applied to construct the risk perception deviations of producers. The risk perception parameter B_t can be estimated directly by state-space approach. Given the equation for B_t defined by SARF and PRT and using the output supply as the measurement equation, the state-space function can be written as:

$$Y_t^{\ *} = Y\left(\overline{P_t}(B_t), \sigma_{p_t}^{2}(B_t), W_t, M^{0}\right)$$
$$B_t = a * B_{t-1} + \beta * f(Z_t) + \varphi_t \quad (3.34)$$

This equation system can be estimated through a Bayesian method to be discussed later.

Given the theoretical model of producer behaviour under risk, models of cow-calf producers' decision-making must also incorporate other factors. As reviewed

[20] The risk perception deviations are approximated by the prediction of outputs based on whole period minus the prediction of outputs based on pre-BSE period because for cow-calf producers, possible responses to an increasing risk perception is to increase their output supplies so as to reduce their cattle inventories.

in Chapter 2, cow-calf production involves both economic and biological factors. The economic factors may be represented by input and output prices (such as feeder calf, slaughter cow and feed grain prices), government policies (such as government subsidies), international market access (such as entering CUSTA or WTO). The biological features of cow-calf production are usually represented by lagged dependent and independent variables. The lags should imply the adjustment costs of cow-calf production (Grundmeier et al., 1989).

3.3.1.1 Model of Feeder Calves

A cow-calf producer maximizes his profits subject to the technology available for animal weight gains, output prices, input costs and discounting rates (Jarvis, 1974, page 492). The cow-calf producer model (Jarvis, 1974) is constructed by first characterizing the profit maximization of feeder calves under certainty.

$$\Pi = Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt \,, \qquad (3.35)$$

where θ, I are respectively the age to be sold[21] and the input combination for a feeder calf. τ is technology in the feeder calf growth, G is the growth function of a feeder calf, r and C are respectively the interest rate and input cost per unit input combination, Pcalf is output price of feeder calves which is exogenous to cow-calf producer decision-making. The price of feeder calves is affected by the age at which it will be sold and input combinations. However, the relationship between feeder calf price and the age at which it will be sold is determined in feeder calf markets where aggregate supply and demand jointly determine an equilibrium. The individual producer cannot change the market prices by changing the age at which a feeder calf will be sold. Further, the feeder calf price is affected by the cow-calf producers' subjective price expectations and price variances due to the biological lags in feeder calf production. By adding risk into cow-calf decision-making model as equation 3.27, assuming expected utility maximization and a unique interior solution of the cow-calf producer, the model can be defined following the approach similar to Holt and Chavas (2002, page 216):

[21] In Jarvis' model, the optimal age is slaughter age while in cow-calf operations in Canada, farmers usually sell their animals to backgrounders, feedlots or packing plants, where the animal is slaughtered. Therefore, the optimal age in this study may be smaller than that in Jarvis' model.

$$V(\overline{Pcalf}(B), \sigma^2_{Pcalf}(B), C, \tau, \gamma, M^0) = Max\ EU$$
$$= Max \int U(M^0 + \Pi)\, dF(Pcalf, B)$$
$$= \arg\max_{\theta,I} EU[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt]$$
$$= \arg\max_{\theta,I} \int U[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt] dF(Pcalf, B) \quad , (3.36)$$

where the expectation and variance of prices are:

$$\overline{Pcalf} = \int Pcalf\, dF(Pcalf, B),$$
$$\sigma^2_{Pcalf} = \int (Pcalf - \overline{Pcalf})^2\, dF(Pcalf, B)\ , \quad (3.37)$$

where F(P,B) is the cumulative distribution function of prices and B is an index of Rothschild –Stiglitz risk. In this study, B is used to represent the level of BSE risk. If B increases, the riskiness associated with output prices for cow-calf producers also increases. The model assumes that risk is generated from output prices. However, it is straightforward to add risks from input costs. The maximization generates the derivatives for θ, I as:

$$E\left\{U_M\left[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * Pcalf * G_{\theta}(\theta, I, \tau)\right\}$$
$$= E\left\{U_M\left[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * \left[r * Pcalf * G(\theta, I, \tau) + C * I\right]\right\}$$
$$E\left\{U_M\left[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * Pcalf * G_I(\theta, I, \tau)\right\}$$
$$= E\left\{U_M\left[M_0 + Pcalf * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * C * \int_0^{\theta} e^{-rt} dt\right\} \quad (3.38)$$

The first derivative suggests that the expected utility of revenue from holding a feeder calf one more period is equal to the expected utility of interest cost and cost saving of selling the feeder calf now and depositing the money in bank. The second derivative suggests that the expected utility of revenue from increasing one more unit of input combination is equal to the expected utility of saving the unit of input combination and depositing the money in the bank, which will generate $C * \int_0^{\theta} e^{-rt} dt$ up to time period θ. Given that the utility function U and the feeder calf growth function G are continuous and twice differentiable, and that the second order sufficient conditions held for expected utility maximization, the optimal solutions for θ, I are:

$$\theta = \theta[M_0, \overline{Pcalf}, \sigma^2_{Pcalf}, r, C, \tau], I = I[M_0, \overline{Pcalf}, \sigma^2_{Pcalf}, r, C, \tau] \quad (3.39)$$

where M_0 is the initial wealth of a cow-calf producer. A first-order Taylor expansion can be applied to θ, I as (Holt and Chavas, 2002, page 219):

$$\begin{aligned}\theta &= a_0 + \frac{\partial\theta}{\partial M_0} * M_0 + \frac{\partial\theta}{\partial\overline{Pcalf}} * \overline{Pcalf} + \frac{\partial\theta}{\partial\sigma^2_{Pcalf}} \sigma^2_{Pcalf} + \frac{\partial\theta}{\partial r} * r + \frac{\partial\theta}{\partial C} * C + \frac{\partial\theta}{\partial\tau} * \tau \\ I &= d_0 + \frac{\partial I}{\partial M_0} * M_0 + \frac{\partial I}{\partial\overline{Pcalf}} * \overline{Pcalf} + \frac{\partial I}{\partial\sigma^2_{Pcalf}} * \sigma^2_{Pcalf} + \frac{\partial I}{\partial r} * r + \frac{\partial I}{\partial C} * C + \frac{\partial I}{\partial\tau} * \tau\end{aligned} \quad (3.40)$$

If the initial wealth is not available, $\frac{\partial\theta}{\partial M_0} * M_0$ and $\frac{\partial I}{\partial M_0} * M_0$ are included in the intercept terms of the optimal age at which steers are to be sold and input combination equations. Technology terms $\frac{\partial\theta}{\partial\tau} * \tau$ and $\frac{\partial I}{\partial\tau} * \tau$ can also be included into the intercept terms if they are not directly observable. The reduced forms of θ, I are:

$$\begin{aligned}\theta &= A_0 + A_1 * \overline{Pcalf} + A_2 * \sigma^2_{Pcalf} + A_3 * C + A_4 * r \\ I &= D_0 + D_1 * \overline{Pcalf} + D_2 * \sigma^2_{Pcalf} + D_3 * C + D_4 * r\end{aligned} \quad (3.41)$$

The optimal age at which feeder calves are to be sold derived from the expected maximization above will determine how many feeder calves are to be sold and how many feeder calves will be kept for inventory. Therefore, the number of feeder calves sold or in inventory can be specified as a function of variables affecting the optimal age at which feeder calves are to be sold as discussed above.

$$Xcalf = \omega_0 + \omega_1 * \overline{Pcalf} + \omega_2 * \sigma^2_{Pcalf} + \omega_3 * C + \omega_4 * r + \omega_5' Others \quad (3.42)$$

$$Scalf = \vartheta_0 + \vartheta_1 * \overline{Pcalf} + \vartheta_2 * \sigma^2_{Pcalf} + \vartheta_3 * C + \vartheta_4 * r + \vartheta_5' Others\ , \quad (3.43)$$

where Xcalf and Scalf are respectively the number of feeder calves sold and in inventory. “Others” are other variables apart from prices that affect the feeder calf supplies such as government programs and producers’ risk management strategies.

The price distribution F(Pcalf,B) or the risk parameter B is affected by all information available for cow-calf producers when they make production decisions. As discussed by Just and Rausser (2002, page 58), the existence of heterogeneity in price expectation formation among producers may be attributed to their cost of obtaining information, accuracy of expectations and the heterogeneity of risk preferences. B is an important factor that causes the heterogeneity of risk preferences among producers. Following an adaptive way (Just and Rausser, 2002, page 61), price distributions can be specified as:

$$\overline{Pcalf_t} = k_1 * \overline{Pcalf_{t-1}} + k_2 * Pcalf_{t-1} + k_3 * B_{t-1}$$

$$\sigma^2_{Pcalf,t} = k_1 * \sigma^2_{Pcalf,t-1} + g_2 * [Pcalf_{t-1} - \overline{Pcalf_{t-1}}]^2 + g_3 * B_{t-1} \qquad (3.44)$$

In essence, equation 3.44 suggests that if the farmer doesn't have any new information available, he/she may solely construct their price distributions based on previous price information. However, if they have new information available, they may update their perceived price distributions. Further, it is assumed that the adjustments in price expectations and variances over their lagged variables are the same for convenience. The risk perception or subjective belief B may be constructed under SARF and PRT as a function of various information indices, which may lead to the heterogeneity of risk preferences among cow-calf producers.

By substituting the price expectations and variances from equation 3.44 into the feeder calf supply and inventory equation 3.42-3.43, the final reduced forms for feeder calf supply and inventory equations are:

$$Xcalf_t = \phi_0 + \phi_1 * Xcalf_{t-1} + \phi_{21} * Pcalf_t + \phi_{22} * (Pcalf_t - \overline{Pcalf_t})^2 + \phi_3 * B_t + \phi_4 * C_t + \phi_5 * C_{t-1} + \phi_6 * r_t + \phi_7 * r_{t-1} + \phi_8 ' Others_t + \phi_9 ' Others_{t-1}$$

$$Scalf_t = \psi_0 + \psi_1 * Scalf_{t-1} + \psi_{21} * Pcalf_t + \psi_{22} * (Pcalf_t - \overline{Pcalf_t})^2 + \psi_3 * B_t + \psi_4 * C_t + \psi_5 * C_{t-1} + \psi_6 * r_t + \psi_7 * r_{t-1} + \psi_8 ' Others_t + \psi_9 ' Others_{t-1}$$

(3.45)

3.3.1.2 Model of Beef Cows

The determination of optimal sold age of beef cows is different from that of feeder calves due to the fact that beef cows can produce calves in the future (Jarvis, 1974, page 498). Therefore, beef cows can be seen as an asset and the expected utility maximization for beef cows should consider the value of calves born in the future.

$$J = \arg\max_{\theta,I} E\{U[M_0 + \Pi]\}$$
$$= \arg\max_{\theta,I} E\{U[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt]\}$$
$$= \arg\max_{\theta,I} \int U[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt] dF(P,B) \quad , \quad (3.46)$$

where $\sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t}$ is the value of calves born up to time θ and P_f is output price of beef cows. The calf price and calf weight at t can be defined as $Pcalf_t$ and $G_{calf}(I,t)$, resulting in an expression for the value of calves born up to time θ as: $\sum_{t=1}^{\theta} \frac{Pcalf_t * G_{calf}(I,t)}{(1+r)^t}$. Assuming $P = (Pf, Pcalf)$, the expectation, variance and covariance of prices are:

$\overline{\mathrm{P}} = \int P \, dF(P,B)$, $\sigma_{\mathrm{p}}^2 = \int (P - \overline{\mathrm{P}})^2 \, dF(P,B)$,

$$\mathrm{Cov}(P_f, Pcalf) = \int (P_f - \overline{P_f})(Pcalf - \overline{Pcalf}) \, dF(P,B) \quad (3.47)$$

The maximization of the expected utility of profit of beef cow production or the solution of function J generates the derivatives for θ, I as:

$$E\left\{U_M\left[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right]\right.$$
$$\left. * \left[P_f * G_\theta'(\theta, I, \tau) * e^{-r\theta} + \frac{Pcalf_\theta * W_{calf}{}'_\theta(I,\theta)}{(1+r)^\theta}\right]\right\}$$
$$= E\left\{U_M\left[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * \left[r * P_f * G(\theta, I, \tau) + C * I\right] * e^{-r\theta}\right\}$$

;

$$E\left\{U_M\left[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right]\right.$$
$$\left. * \left[P_f * G_I(\theta, I, \tau) * e^{-r\theta} + \frac{Pcalf_\theta * G_{calf}{}'_I(I,\theta)}{(1+r)^\theta}\right]\right\} \quad (3.48)$$
$$= E\left\{U_M\left[M_0 + \sum_{t=1}^{\theta} \frac{Cal(I,t)}{(1+r)^t} + P_f * G(\theta, I, \tau) * e^{-r\theta} - C * I * \int_0^{\theta} e^{-rt} dt\right] * C * \int_0^{\theta} e^{-rt} dt\right\}$$

The first derivative suggests that the expected utility of revenue from holding a beef cow one more period including the weight gain of the beef cow and the calf born is equal to the expected utility of interest and cost saving from the selling of the beef cow and depositing the money in the bank. The second derivative suggests that the expected utility of revenue from increasing one more unit of input combination including weight gain of the beef cow and the calf born is equal to the expected utility of saving the unit of input combination and depositing the money in the bank, which will generate $C*\int_0^{\theta} e^{-rt}dt$ up to time period θ. The value of calves born in year θ, $\frac{Cal(I,\theta)}{(1+r)^{\theta}}$, depends on the probability that the cow will have a calf in year θ, the probability that the calf will be male or female, the discounting rate and the expected calf price and weight in year θ (Jarvis, 1974).

Based on the same logic as in the feeder calf supply model, the number of beef cows sold or in inventory can be specified as:

$$X_f = \omega_0 + \omega_1'\overline{P} + \omega_2'\sigma_P^2 + \omega_3 * \text{cov}(P_f, Pcalf) + \omega_4 * C + \omega_5 * r + \omega_6'Others \qquad (3.49)$$

$$S_f = \vartheta_0 + \vartheta_1'\overline{P} + \vartheta_2'\sigma_P^2 + \vartheta_3 * \text{cov}(P_f, Pcalf) + \vartheta_4 * C + \vartheta_5 * r + \vartheta_6'Others\ , \qquad (3.50)$$

where X_f and S_f are respectively the number of beef cows sold and in inventory. “Others” are other variables in addition to prices that affect the beef cow supply such as government programs and producers’ risk management strategies. It should be noted that the output prices in beef cow supply equation include prices of feeder calves and slaughter cows. Similar to the model of feeder calves, partial adjustments in price expectations, variances and covariances over their lagged variables are assumed.

$$\overline{P_t} = k_1 * \overline{P_{t-1}} + k_2 * P_{t-1} + k_3 * B_{t-1}\ ; \sigma_{P,t}^2 = k_1 * \sigma_{P,t-1}^2 + g_2 * [P_{t-1} - \overline{P_{t-1}}]^2 + g_3 * B_{t-1}$$

$$\text{Cov}(P_{f,t}, Pcalf_t) = \text{k}_1 * \text{Cov}(P_{f,t-1}, Pcalf_{t-1})$$
$$+\text{f}_2 * \left(P_{f,t-1} - \overline{P_{f,t-1}}\right)\left(Pcalf_{t-1} - \overline{Pcalf_{t-1}}\right) + \text{f}_3 * B_{t-1} \qquad (3.51)$$

By substituting the price expectations, variances and covariances into the beef cow supply and inventory equations, the final reduced forms for beef cow supply and inventory equations are:

$$X_{f,t} = \phi_0 + \phi_1 * X_{t-1} + \phi_{21} * Pcalf_t + \phi_{22} * (Pcalf_t - \overline{Pcalf}_t)^2 + \phi_{31} * P_{f,t} + \phi_{32} * (P_{f,t} - \overline{P_{f,t}})^2$$
$$+ \phi_{33} * (Pcalf_t - \overline{Pcalf}_t)(P_{f,t} - \overline{P_{f,t}}) + \phi_4 * B_t + \phi_5 * C_t + \phi_6 * C_{t-1} + \phi_7 * r_t + \phi_8 * r_{t-1}$$
$$+ \phi_9'Others_t + \phi_{10}'Others_{t-1}$$

$$S_{f,t} = \psi_0 + \psi_1 * S_{f,t-1} + \psi_{21} * Pcalf_t + \psi_{22} * (Pcalf_t - \overline{Pcalf}_t)^2 + \psi_{31} * P_{f,t} + \psi_{32} * (P_{f,t} - \overline{P_{f,t}})^2$$
$$+ \psi_{33} * (Pcalf_t - \overline{Pcalf}_t)(P_{f,t} - \overline{P_{f,t}}) + \psi_4 * B_t + \psi_5 * C_t + \psi_6 * C_{t-1} + \psi_7 * r_t + \psi_8 * r_{t-1} \tag{3.52}$$
$$+ \psi_9 ' Others_t + \psi_{10} ' Others_{t-1}$$

Although we have discussed the methodologies of incorporating risk perceptions about BSE (B_t) into the behavioural models of cow-calf producers for feeder calves and beef cows, only beef cow inventory and slaughter cow supply equations will be analyzed in the empirical sections. This is due to the fact that the beef cow inventory is the most fundamental decision of cow-calf operations and beef cows account for the most significant investment in cattle inventories for cow-calf producers.

As the opposite aspect of beef cow inventory, cow slaughter /supply is obviously affected by the same variables as beef cow inventory but there are some unique aspects of the BSE outbreak (2003) which could also impact cow slaughter/supply. First, border closed to trade in live cattle and beef immediately. As the markets had evolved prior to May, 2003 many older animals, such as cull cows from beef and dairy herds, had moved to the United States for slaughter. Older animals, being the ones most likely to exhibit BSE, have been kept out of international trade even as trade restrictions have gradually loosened. At the same time as all of the animals were not allowed to move internationally, export markets for Canadian beef were also decreased. Thus, more animals were available to be slaughtered in Canada at the time when prices for beef and export markets for beef were not optimal. As a result many of the facilities in Canada restricted the number of cull cows they would slaughter. Over time the market for cull cows has adjusted to changing Canadian trade positions in the international beef market at a different level than existed prior to BSE.

Behavioural decisions about whether to maintain cows in inventory versus slaughter them may now be affected by changed risk perceptions associated with raising calves as a business proposition as well as the dramatic effects of closed borders and limited access to slaughter capacity that occurred directly post BSE after May, 2003. Slaughter cow supply/slaughter is likely to be the most affected due by BSE outbreaks in Canada. BSE risk perceptions can be reflected by changes in beef cow inventories and/or slaughter cow supplies. As the most basic decision of cow-calf producers, changes in beef cow inventories are the best alternative to estimate risk perceptions about BSE. However, since only annual beef cow inventory data is available and there is a need to incorporate cull cows from dairy herds in the aggregate cow slaughter variable, slaughter cow supply equation can also be used to estimate risk perceptions about BSE.

As well as the incorporation of the risk parameters into the model and the selection of appropriate functional forms, the data are also a crucial consideration in estimation. Different econometric techniques are required for time series data and panel data for cow-calf producers. Given the above considerations, the empirical models for beef cow inventories and slaughter cow supplies based on different types of data are presented below.

3.3.1.2.1 Model of Beef Cow Inventory in Canada

Cow-calf producers view their cows as both consumption and capital goods (Jarvis, 1974). On one hand, cows can breed stocker calves every year and therefore, provide a continuous income flow in the future. On the other, cows can be culled and sold to slaughterers to generate certain current revenue. Cow-calf producers need to make their decisions on adjustment of beef cow inventory based on their expectations of stocker calf prices and slaughter cow prices. Also, beef cow inventory is subject to other types of factors such as biological production lags, seasonality, weather changes, input prices, producer subsidies, structural changes and international trade changes (Maki, 1957; Jarvis, 1974; Tryfos, 1974; Chan, 1981; Marsh, 1984; Paarsch, 1985; Okyere and Johnson, 1987; Grundmeier et al., 1989; Marsh, 1991; Johnson et al., 1998; Aadland and Bailey, 2001; Kuchler and Tegene, 2006; Marsh, 2007). There are many studies concerning the Canadian beef sector (Tryfos, 1974; Kulshreshtha and Wilson, 1974; Martin and Haack, 1977; Coleman and Meilke, 1988; Cranfield and Goddard,1999; Mbaga, 2000; Grier, 2005; Rude et al., 2007), in which different functional forms such as distributed lags (Martin and Haack, 1977; Coleman and Meilke, 1988), autoregressive (partial adjustment) (Tryfos, 1974) or autoregressive distributed lag (Mbaga, 2000) are applied to address various factors affecting beef cow inventories. These previous studies provide clues about the functional specifications and the variables to be included in cow-calf decision-making. Based on equation 3.47 but removing the risk perception variable, a partial adjustment model of beef cow inventory is constructed as following for time series data and panel data[22]:

Beef cow inventory equation[23] based on time series data:

$$BWI_t = a_0 + a_1 * BWI_{t-1} + a_{21} * PFC_t + a_{22} * SSDPFC_t + a_{31} * PC_t + a_{32} * SSDPC_t + a_{33} * [PFC_t - E(PFC_t)] * [PC_t - E(PC_t)] + a_{41} * r_t + a_{42} * r_{t-1} + a_{51} * FP_t + a_{52} * FP_{t-1} + a_{61} * t + a_{62} * t_{-1} + a_7 * D1988 + a_8 * D1995 + a_9 * DBSE \tag{3.53}$$

Beef cow inventory equation based on panel data:

$$BWI_{i,t} = a_{i,0} + a_{i,1} * BWI_{i,t-1} + a_{i,21} * PFC_{i,t} + a_{i,22} * SSDPFC_{i,t} + a_{i,31} * PC_{i,t} + a_{i,32} * SSDPC_{i,t} + a_{i,33} * [PFC_t - E(PFC_t)] * [PC_t - E(PC_t)] + a_{i,41} * r_t + a_{i,42} * r_{t-1} + a_{i,51} * FP_{i,t} + a_{i,52} * FP_{i,t-1} + a_{i,61} * t + a_{i,62} * t_{-1} + a_{i,7} * D1988 + a_{i,8} * D1995 + a_{i,9} * DBSE \tag{3.54}$$

where BWI_t is the beef cow inventory at time t, $BWI_{i,t}$ is the beef cow inventory in region i at time t, and i represents region i (e.g. region 1 is Alberta, region 2 is B.C./Saskatchewan/Manitoba, region 3 is Ontario, and region 4 is Quebec/ Atlantic provinces). r_t is the bank rate at time t, which is the same across four regions. FP_t is the feed price at time t, $FP_{i,t}$ is the feed price in region i at time t, PC_t is the slaughter cow price at time t, $PC_{i,t}$ is the slaughter cow price in region i at time t, $SSDPC_t$ is the squared standard deviations of slaughter cow price at time t, $SSDPC_{i,t}$ is the squared standard deviations of slaughter cow price in region i at time t, PFC_t is the feeder calf price at time t, $PFC_{i,t}$ is the feeder calf price in region i at time t, $SSDPFC_t$ is the squared standard deviations of feeder calf price at time t, $SSDPFC_{i,t}$ is the squared standard deviations of feeder calf price in

[22] The panel data used is regionally-augmented panel data for Alberta, B.C. and Sask./Man., Ontario, Quebec and Atlantic provinces.

[23] The producer subsidy estimates should also be incorporated into the beef cow inventory equation as well. However, we only have the data of producer subsidy estimates (PSE) starting from 1979. For the period 1941-1979, we don't have the data of PSE. If we impute the missing observations by zero or by linear imputation, the estimation results showed an insignificant effect of PSE and the removal of PSE can actually increase the model fitness. Therefore, the PSE variable is not included in the beef cow inventory equation.

region i at time t, t is the time trend, $D1995$ is a dummy variable and D1995= $\begin{cases} 1 \; if \; t \geq 1995 \\ 0 \; otherwise \end{cases}$, D1998 is a dummy variable and D1988= $\begin{cases} 1 \; if \; t \geq 1988 \\ 0 \; otherwise \end{cases}$, DBSE is a dummy variable and DBSE= $\begin{cases} 1 \; if \; t \geq 2003 \\ 0 \; otherwise \end{cases}$, and $a_{j,} a_{i,j}$ are the parameters in beef cow inventory equations.

The squared standard deviations of feeder calf prices and slaughter cow prices are incorporated to account for the impacts of price risk in beef cow inventories. The price expectations are computed by the moving averages of prices in the previous periods (Behrman,1968). There are other specifications of approximation of price expectations and variations as reviewed in section 2.3. These approaches, though advanced, add the complexity of model derivation and estimation. Therefore, we use a simple method like three-period moving averages of prices to represent price expectations. Nonetheless, we have incorporated the BSE risk perceptions as a factor affecting price expectations and risks. The SSDPFC and SSDPC are calculated as squared standard deviations of feeder calf (slaughter cow) prices around their three-period moving average prices. The bank rates and feed prices are incorporated into the beef cow inventory equation to account respectively for the input costs of capital and feed grain. D1988 and D1995 are incorporated to account for the impacts of the first Canada-U.S. Free Trade Agreement (CUSTA) in 1988 and Canada being a signatory to the WTO in 1995 or the elimination of Crow Rates. DBSE is applied to track the impacts of the BSE outbreak in Canada in 2003. The model is estimated over provincial time series data and regionally-segmented panel data. For the panel data, however, equation 3.54 is established as a general form with all the parameters regionally specific. If the data poolability test (Baltagi, 2001) suggests that the individual regional data are poolable or have the same slope parameters in the beef cow inventory equation, equation 3.54 can be reduced to a fixed effect model (only intercepts may be regionally specific).

We can also use the price ratios between feeder calf prices (slaughter cow prices) and feed grain prices instead of real prices, which were also widely used in the previous literature concerning cow-calf production (Kulshreshtha and Wilson, 1974; Rucker et al., 1984; Rude et al., 2007). The expectations of price ratios are approximated by the three-period moving average of previous price ratios (Chavas and Kraus, 1990). The equation forms with price ratios are as follows:

Beef cow inventory equation based on time series data:

$$BWI_t = a_0 + a_1 * BWI_{t-1} + a_{21} * PFCFP_t + a_{22} * SSDPFCFP_t + a_{31} * PCFP_t + a_{32} * SSDPCFP_t + a_{33} * [PFCFP_t - E(PFCFP_t)] * [PCFP_t - E(PCFP_t)] + a_{41} * r_t + a_{42} * r_{t-1} + a_{61} * t + a_{62} * t_{-1} + a_7 * D1988 + a_8 * D1995 + a_9 * DBSE \quad (3.55)$$

Beef cow inventory equation based on panel data:

$$BWI_{i,t} = a_{i,0} + a_{i,1} * BWI_{i,t-1} + a_{i,21} * PFCFP_{i,t} + a_{i,22} * SSDPFCFP_{i,t} + a_{i,31} * PCFP_{i,t} + a_{i,32} * SSDPCFP_{i,t} + a_{i,33} * [PFCFP_t - E(PFCFP_t)] * [PCFP_t - E(PCFP_t)] + a_{i,41} * r_t + a_{i,42} * r_{t-1} + a_{i,61} * t + a_{i,62} * t_{-1} + a_{i,7} * D1988 + a_{i,8} * D1995 + a_{i,9} * DBSE \quad (3.56)$$

where $PFCFP = \frac{PFC}{FP}$, $PCFP = \frac{PC}{FP}$, $SSDPFCFP = SSD\left(\frac{PFC}{FP}\right)$, $SSDPCFP = SSD\left(\frac{PC}{FP}\right)$, and SSD is squared standard deviations. The short run and long run price elasticities are calculated as:

Short run price elasticities based on time series data:

$$E_{S,PFCFP} = a_{21} * \overline{PFCFP}/\overline{BWI} \ , E_{S,PCFP} = a_{31} * \overline{PCFP}/\overline{BWI}$$

$$E_{S,SSDPFCFP} = a_{22} * \overline{SSDPFCFP}/\overline{BWI} \ , E_{S,SSDPCFP} = a_{32} * \overline{SSDPCFP}/\overline{BWI}$$

$$E_{S,COV} = a_{33} * \overline{[PFCFP \quad - E(PFCFP \quad)] * [PCFP \quad - E(PCFP \quad)]}/\overline{BWI} \quad (3.57)$$

Long run price elasticities based on time series data:

$$E_{L,PFCFP} = a_{21}/(1 - a_4) * \overline{PFCFP}/\overline{BWI} \ , E_{L,PCFP} = a_{31}/(1 - a_4) * \overline{PCFP}/\overline{BWI}$$

$$E_{L,SSDPFCFP} = a_{22}/(1 - a_4) * \overline{SSDPFCFP}/\overline{BWI} \ , E_{L,SSDPCFP} = a_{32}/(1 - a_4) * \overline{SSDPCFP}/\overline{BWI}$$

$$E_{L,COV} = a_{33}/(1 - a_4) * \overline{[PFCFP \quad - E(PFCFP \quad)] * [PCFP \quad - E(PCFP \quad)]}/\overline{BWI} \quad (3.58)$$

Short run price elasticities based on panel data:

$$E_{S,PFCFP,i} = a_{i,21} * \overline{PFCFP_i}/\overline{BWI_i} \ , E_{S,PCFP,i} = a_{i,31} * \overline{PCFP_i}/\overline{BWI_i}$$

$$E_{S,SSDPFCFP,i} = a_{i,22} * \overline{SSDPFCFP_i}/\overline{BWI_i} \ , E_{S,SSDPCFP,i} = a_{i,32} * \overline{SSDPCFP_i}/\overline{BWI_i}$$

$$E_{S,COV,i} = a_{i,33} * \overline{[PFCFP_i - E(PFCFP_i)] * [PCFP_i - E(PCFP_i)]}/\overline{BWI_i} \quad (3.59)$$

Long run price elasticities based on panel data:

$$E_{L,PFCFP,i} = a_{i,21}/(1 - a_{i,4}) * \overline{PFCFP_i}/\overline{BWI_i} \ , E_{L,PCFP,i} = a_{i,31}/(1 - a_{i,4}) * \overline{PCFP_i}/\overline{BWI_i}$$

$$E_{L,SSDPFCFP,i} = a_{i,22}/(1 - a_{i,4}) * \overline{SSDPFCFP_i}/\overline{BWI_i}, E_{L,SSDPCFP,i} = a_{i,32}/(1 - a_{i,4}) * \overline{SSDPCFP_i}/\overline{BWI_i}$$

$$E_{L,COV,i} = a_{i,33}/(1 - a_{i,4}) * \overline{[PFCFP_i - E(PFCFP_i)] * [PCFP_i - E(PCFP_i)]}/\overline{BWI_i} \quad (3.60)$$

where $\overline{x}$ is the mean of variable and it is approximated by a three-year moving average of prices for simplicity (Behrman, 1968). E_S and E_L are, respectively, short run and long run price elasticities. The theoretical and empirical models of slaughter cow supplies are specified in the following section.

3.3.1.2.2 Model of Slaughter Cow Supply in Canada

Based on equation 3.47, the slaughter cow supply equation is (Just, 1974, equation 9; Just, 1976):

$$\begin{aligned} X_{f,t} &= \phi_0 + \phi_1 * X_{t-1} + \phi_{21} * PFC_t + \phi_{22} * (PFC_t - \overline{PFC}_t)^2 + \phi_{31} * PC_t + \phi_{32} * (PC_t - \overline{PC}_t)^2 \\ &+ \phi_{33} * (PFC_t - \overline{PFC}_t)(PC_t - \overline{PC}_t) + \phi_4 * B_t + \phi_5 * FP_t + \phi_6 * FP_{t-1} + \phi_7 * r_t + \phi_8 * r_{t-1} \\ &+ \phi_9 ' Others_t + \phi_{10} ' Others_{t-1} \end{aligned} \quad , (3.61)$$

where $X_{f,t}$ is the number of beef cows sold and "Others" are other variables except prices that affect beef cow supply such as price risks, government support programs, previous beef cow inventories, dairy cow inventories, and producers' risk management strategies[24]. B_t is the risk perception parameter specified to BSE, which will be estimated through the predictive difference approach and the state-space approach. The price expectations are approximated by a three-year moving average of prices. The price risks are represented by the standard deviations of prices of feeder calves or slaughter cows around their price expectations. The government support programs can be approximated by the producer subsidy estimates (Harley, 1996). The risk management strategies adopted by producers may be different and hard to be characterized. Therefore, they are incorporated into the intercept of slaughter cow equation. The input costs of beef cows are represented by the prices of feed grain. Also, the quarterly dummies and time trend variables are incorporated to track the seasonality and structural changes of slaughter cow supplies. The dummies for CUSTA and WTO (or the elimination of Crow Rate) are also incorporated to account for the impacts of first Canada-U.S. Free Trade Agreement (CUSTA) in 1988 and Canada being a member of WTO in 1995/the elimination of Crow Rate.

[24] Dummies about significant changes in slaughter cow demand are also created and incorporated in the slaughter cow supply models based on time series data and panel data. These dummies are equal 1 if cow slaughter is less than 20% of annual monthly average in 12 months before BSE and zero otherwise. Dummies about border reopening from other countries to Canadian beef and live cattle are also incorporated.

We can also use the price ratios between feeder calf prices (slaughter cow prices) and feed grain prices instead of real prices, which were also widely used in the previous literature about cow-calf production (Kulshreshtha and Wilson, 1974; Rucker et al., 1984; Rude et al., 2007). The slaughter cow supply equations with price ratios are:

Slaughter cow supply equation based on time series data:

$$\begin{aligned} X_{f,t} &= \phi_0 + \phi_1 * X_{f,t-1} + \phi_{21} * PFCFP_t + \phi_{22} * [PFCFP_t - E(PFCFP_t)]^2 + \phi_{31} * PCFP_t \\ &+ \phi_{32} * [PCFP_t - E(PCFP_t)]^2 + \phi_{33} * [PFCFP_t - E(PFCFP_t)][PCFP_t - E(PCFP_t)] \\ &+ \phi_4 * B_t + \phi_7 * r_t + \phi_8 * r_{t-1} + \phi_9 * PSE_t + \phi_{10} * PSE_{t-1} + \phi_{11} * BWI_{t-1} + \phi_{12} * BWI_{t-2} \\ &+ \phi_{13} * DWI_{t-1} + \phi_{14} * DWI_{t-2} + \phi_{15}' quarter_t + \phi_{16} * Time + \phi_{17} * D19881 + \phi_{18} * D19951 \end{aligned} \tag{3.62}$$

Slaughter cow supply equation based on panel data:

$$\begin{aligned} X_{f,i,t} &= \phi_{i,0} + \phi_{i,1} * X_{f,i,t-1} + \phi_{i,21} * PFCFP_{i,t} + \phi_{i,22} * [PFCFP_{i,t} - E(PFCFP_{i,t})]^2 + \phi_{i,31} * PCFP_{i,t} \\ &+ \phi_{i,32} * [PCFP_{i,t} - E(PCFP_{i,t})]^2 + \phi_{i,33} * [PFCFP_{i,t} - E(PFCFP_{i,t})][PCFP_{i,t} - E(PCFP_{i,t})] \\ &+ \phi_{i,4} * B_{i,t} + \phi_{i,7} * r_t + \phi_{i,8} * r_{t-1} + \phi_{i,9} * PSE_{i,t} + \phi_{i,10} * PSE_{i,t-1} + \phi_{i,11} * BWI_{i,t-1} + \phi_{i,12} * BWI_{i,t-2} \\ &+ \phi_{i,13} * DWI_{i,t-1} + \phi_{i,14} * DWI_{i,t-2} + \phi_{i,15}' quarter_t + \phi_{i,16} * Time + \phi_{i,17} * D19881 + \phi_{i18} * D19951 \end{aligned} \tag{3.63}$$

where $PFCFP_t = Pcalf_t / FP_t$, $PCFP_t = PC_t / FP_t$, i is region i, r is interest rate, and PSE is producer subsidy estimate. BWI and DWI are, respectively, beef cow inventories and dairy cow inventories. Quarter is a vector of quarterly dummies for quarter 1, quarter 2 and quarter 3 (quarter 4 is removed to avoid multicollinearity with intercept). Time is a time trend to account for structural changes in slaughter cow supplies. D19881= $\begin{cases} 1 \; if \; t \geq \text{the first quarter, 1988} \\ 0 \; otherwise \end{cases}$ and D19951 = $\begin{cases} 1 \; if \; t \geq \text{the first quarter, 1995} \\ 0 \; otherwise \end{cases}$. The short run and long elasticities associated with feeder calf prices and slaughter cow prices are calculated as:

Short run price elasticities based on time series data:

$$EC_{S,PFCFP} = \phi_{21} * \frac{\overline{PFCFP}}{\overline{X_f}}, \; EC_{S,PCFP} = \phi_{31} * \frac{\overline{PCFP}}{\overline{X_f}} \tag{3.64}$$

$$EC_{S,SSDPFCFP} = \phi_{22} * \frac{\overline{[PFCFP - E(PFCFP)]^2}}{\overline{X_f}}, EC_{S,SSDPCFP} = \phi_{32} * \frac{\overline{[PCFP - E(PCFP)]^2}}{\overline{X_f}} \tag{3.65}$$

$$EC_{S,COVPCFP} = \phi_{33} * \frac{\overline{[PFCFP - E(PFCFP)] * [PCFP - E(PCFP)]}}{\overline{X_f}} \tag{3.66}$$

Long run price elasticities based on time series data:

$$EC_{L,PFCFP} = \frac{\phi_{21}}{1-\phi_1} * \frac{\overline{PFCFP}}{\overline{X_f}}, \; EC_{L,PCFP} = \frac{\phi_{31}}{1-\phi_1} * \frac{\overline{PCFP}}{\overline{X_f}} \tag{3.67}$$

$$EC_{L,SSDPFCFP} = \frac{\phi_{22}}{1-\phi_1} * \frac{\overline{[PFCFP-E(PFCFP)]^2}}{\overline{X_f}} \text{ , } EC_{L,SSDPCFP} = \frac{\phi_{32}}{1-\phi_1} * \frac{\overline{[PCFP-E(PCFP)]^2}}{\overline{X_f}} \quad (3.68)$$

$$EC_{L,COVPCFP} = \frac{\phi_{33}}{1-\phi_1} * \frac{\overline{[PFCFP-E(PFCFP)]*[PCFP-E(PCFP)]}}{\overline{X_f}} \quad (3.69)$$

Short run price elasticities based on panel data:

$$EC_{S,PFCFP,i} = \phi_{i,21} * \frac{\overline{PFCFP_i}}{\overline{X_{f,i}}} \text{ ; } EC_{S,PCFP,i} = \phi_{i,31} * \frac{\overline{PCFP_i}}{\overline{X_{f,i}}} \quad (3.70)$$

$$EC_{S,SSDPFCFP,i} = \phi_{i,22} * \frac{\overline{[PFCFP_i-E(PFCFP_i)]^2}}{\overline{X_{f,i}}}, EC_{S,SSDPCFP,i} = \phi_{i,32} * \frac{\overline{[PCFP_i-E(PCFP_i)]^2}}{\overline{X_{f,i}}} \quad (3.71)$$

$$EC_{S,COVPCFP,i} = \phi_{i,33} * \frac{\overline{[PFCFP_i-E(PFCFP_i)]*[PCFP_i-E(PCFP_i)]}}{\overline{X_{f,i}}} \quad (3.72)$$

Long run price elasticities based on panel data:

$$EC_{L,PFCFP,i} = \frac{\phi_{i,21}}{1-\phi_{i,1}} * \frac{\overline{PFCFP_i}}{\overline{X_{f,i}}} \text{ , } EC_{L,PCFP,i} = \frac{\phi_{i,31}}{1-\phi_{i,1}} * \frac{\overline{PCFP_i}}{\overline{X_{f,i}}} \quad (3.73)$$

$$EC_{L,SSDPFCFP,i} = \frac{\phi_{i,22}}{1-\phi_{i,1}} * \frac{\overline{[PFCFP_i-E(PFCFP_i)]^2}}{\overline{X_{f,i}}}, EC_{L,SSDPCFP,i} = \frac{\phi_{i,32}}{1-\phi_{i,1}} * \frac{\overline{[PCFP_i-E(PCFP_i)]^2}}{\overline{X_{f,i}}}$$

$$EC_{L,COVPCFP,i} = \frac{\phi_{i,33}}{1-\phi_{i,1}} * \frac{\overline{[PFCFP_i-E(PFCFP_i)]*[PCFP_i-E(PCFP_i)]}}{\overline{X_{f,i}}} \quad (3.74)$$

Given the discussion of theoretical and empirical models of cow-calf operations, the risk perception about BSE (B_t) will be approximated or estimated through predictive difference approach and state-space approach. These methods will be discussed in the following sections.

3.3.2 Slaughter Cow Supply Model with Predictive Difference Approach and Time Series Data

The slaughter cow supply equation is applied to track the predictive difference due to BSE outbreak in 2003. The empirical specifications of cow supply equations for Western Canada and Eastern Canada are illustrated in equation 3.62. The risk perception deviations about BSE are approximated by the prediction differences. The flow chart for the predictive difference approach is shown in Figure 3.5.

Similar to the consumer model based on the predictive difference approach, the slaughter cow supply equation is estimated over two time periods. The first is from the period before the BSE outbreak in Canada (May, 2003). The other is from the entire period available. Two predictions are made for the time period after the BSE-infected cow was found in Canada at May, 2003. The difference in slaughter cow supplies from the two predictions is estimated as a proxy for risk perception deviations due to BSE and the final risk perception equation for estimation is:

$$\text{Pd}_{\text{f, t}} = -A_0 * (1-\alpha) + \alpha * \text{Pd}_{\text{f, t-1}} + \beta * (l_1 * \text{Gross Media Coverage for BSE}_{\text{t}} + l_2 ' \text{Media Subject Indices for BSE}_{\text{t}} + l_3 * T) + \varepsilon_t - \alpha * \varepsilon_{t-1} \ , \quad (3.75)$$

where $\alpha + \beta = 1$. The predicted risk perception measures can be computed by:

$$\hat{POR}_t = \hat{\alpha} * \hat{POR}_{t-1} + \hat{\beta} * (\hat{l}_1 * \text{Gross Media Coverage of BSE}_{\text{t}} + \hat{l}_2 ' \text{Media Subject Indices of BSE}_{\text{t}} + \hat{l}_3 * T) \ , \quad (3.76)$$

where $\hat{POR}_0 = \hat{A}_0 ; \hat{\alpha}, \hat{\beta}, \hat{l}_1$ are estimated parameters.

Figure 3.5 Slaughter Cow Supply Equation and Risk Perception Estimation by Predictive Difference Approach and Time Series Data

Slaughter cow supply:

$$X_{f,t} = \phi_0 + \phi_1 * X_{f,t-1} + \phi_{21} * PFCFP_t + \phi_{22} * [PFCFP_t - E(PFCFP_t)]^2 + \phi_{31} * PCFP_t + \phi_{32} * [PCFP_t - E(PCFP_t)]^2 + \phi_{33} * [PFCFP_t - E(PFCFP_t)][PCFP_t - E(PCFP_t)] + \phi_7 * r_t + \phi_8 * r_{t-1} + \phi_9 * PSE_t + \phi_{10} * PSE_{t-1} + \phi_{11} * BWI_{t-1} + \phi_{12} * BWI_{t-2} + \phi_{13} * DWI_{t-1} + \phi_{14} * DWI_{t-2} + \phi_{15} ' quarter_t + \phi_{16} * Time + \phi_{17} * D19881 + \phi_{18} * D19951$$

The slaughter cow supply equation is estimated based on the data before the BSE outbreak in Canada in the second quarter of 2003 (1st quarter of 1970 to 1st quarter of 2003). Based on the parameters estimated, the predictions of slaughter cow supply $X_{f,t}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $Xhat\ 1_{f,t}$

The slaughter cow supply equation is estimated based on the data for the entire sample[a] (1st quarter of 1970 to 4th quarter of 2008) or the post-BSE sample (2nd quarter of 2003 to 4th quarter of 2008). Based on the parameters estimated, the predictions of slaughter cow supply $X_{f,t}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $Xhat\ 2_{f,t}$

$$\text{Pd}_{\text{f, t}} = Xhat\ 2_{f,t} - Xhat\ 1_{f,t}$$

$$\text{Pd}_{\text{f, t}} = devPOR_t + \varepsilon_t = -A_0 * (1-\alpha) + \alpha * devPOR_{t-1} + \beta * f_t(Media_t) + \varepsilon_t$$

$$\text{Pd}_{\text{f, t}} = -A_0 * (1-\alpha) + \alpha * \text{Pd}_{\text{f, t-1}} + \beta * (k_1 * \text{Gross Media Coverage of BSE}_{\text{t}} + k_2 ' \text{Media Subject Indices of BSE}_{\text{t}} + k_4 * T) + \varepsilon_t - \alpha * \varepsilon_{t-1}$$

a: The slaughter cow supply equation based on entire period will be tested for structural changes in slope parameters.

where $\alpha+\beta=1$, $X_{f,t}$ is the slaughter cow supply at t, $PFCFP_t$ is the ratio of feeder calf price over feed grain price at t, $PCFP_t$ is the ratio of slaughter cow price over feed grain price at t, r_t is the interest rate at t, PSE_t is the producer subsidy estimate at t, BWI_t is the beef cow inventory at t, DWI_t is the dairy cow inventory at t, $quarter_i$ is the vector of quarterly dummies (i=1,2,3), $Time$ is time trend variable, $\mathrm{Pd}_{f,t}$ is the predictive difference at t, D19881 is a dummy variable and $\mathrm{D19881} = \begin{cases} 1 \text{ if } t \geq \text{the first quarter, 1988} \\ 0 \text{ otherwise} \end{cases}$, D19951 is a dummy variable and $\mathrm{D19951} = \begin{cases} 1 \text{ if } t \geq \text{the first quarter, 1995} \\ 0 \text{ otherwise} \end{cases}$, $devPOR_t$ is the risk perception deviation at t, A_0 is the baseline risk to be estimated, $Media_i$ are media indices about BSE for cow-calf producers, $\varepsilon_{f,t}$ and ε_t are random errors, and $\phi_i, \alpha, \beta, k_i$ are parameters to be estimated.

3.3.3 Slaughter Cow Supply Model with Predictive Difference Approach and Regionally disaggregated Panel Data

Slaughter cow supply equation is also estimated over the panel data from four augmented regions including Alberta (region 1), B.C./Manitoba/Saskatchewan (region 2), Ontario (region 3), Quebec/Atlantic provinces (region 4). The slaughter cow supply model by region is used to track different production structures in Western and Eastern Canada such as the differences in feed grain inputs and differences in scales of cow-calf production. Further, most BSE-infected cows were found in Alberta and B.C. and therefore, it is reasonable to expect more changes occurred in these regions. The empirical specifications of cow slaughter/supply based on panel data are illustrated in equation 3.58. The flow chart of estimations based on predictive different approach and panel data are illustrated (Figure 3.6).

Figure 3.6 Slaughter Cow Supply Equation and Risk Perception Estimation by Predictive Difference Approach and Panel Data

Slaughter cow supply:

$$X_{f,i,t} = \phi_{i,0} + \phi_{i,1} * X_{f,i,t-1} + \phi_{i,21} * PFCFP_{i,t} + \phi_{i,22} * [PFCFP_{i,t} - E(PFCFP_{i,t})]^2 + \phi_{i,31} * PCFP_{i,t}$$
$$+ \phi_{i,32} * [PCFP_{i,t} - E(PCFP_{i,t})]^2 + \phi_{i,33} * [PFCFP_{i,t} - E(PFCFP_{i,t})][PCFP_{i,t} - E(PCFP_{i,t})]$$
$$+ \phi_{i,7} * r_t + \phi_{i,8} * r_{t-1} + \phi_{i,9} * PSE_{i,t} + \phi_{i,10} * PSE_{i,t-1} + \phi_{i,11} * BWI_{i,t-1} + \phi_{i,12} * BWI_{i,t-2}$$
$$+ \phi_{i,13} * DWI_{i,t-1} + \phi_{i,14} * DWI_{i,t-2} + \phi_{i,15}' quarter_t + \phi_{i,16} * Time + \phi_{i,17} * D19881 + \phi_{i18} * D19951$$

Slaughter cow supply equation is estimated based on the data before BSE outbreak in Canada in the second quarter of 2003 (1st quarter of 1970 to 1st quarter of 2003). Based on the parameters estimated, the predictions of slaughter cow supply $X_{f,i,t}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $Xhat1_{f,i,t}$

Slaughter cow supply equation is estimated based on the data of whole sample (1st quarter of 1970 to 4st quarter of 2008) or the post-BSE sample (2nd quarter of 2003 to 4st quarter of 2008). Based on the parameters estimated, the predictions of slaughter cow supply $X_{f,i,t}$ after the BSE outbreak in Canada in the second quarter of 2003 are obtained and named as: $Xhat2_{f,i,t}$

$$\text{Pd}_{f,i,t} = Xhat2_{f,i,t} - Xhat1_{f,i,t}$$

$$\text{Pd}_{f,i,t} = devPOR_{i,t} + \varepsilon_{i,t} = -A_{i,0} * (1 - \alpha_i) + \alpha_i * devPOR_{i,t-1} + \beta_i * f_{i,t}(Media_{i,t}) + \varepsilon_{i,t}$$

$$\text{Pd}_{f,i,t} = -A_{i,0} * (1 - \alpha_i) + \alpha_i * \text{Pd}_{f,i,t-1} + \beta_i * (k_{i,1} * \text{Gross Media Coverage of BSE}_{i,t}$$
$$+ k_{i,2}' \text{Media Subject Indices of BSE}_{i,t} + k_{i,4} * T) + \varepsilon_{i,t} - \alpha_i * \varepsilon_{i,t-1}$$

where $\alpha_i + \beta_i = 1$.

where $X_{f,i,t}$ is the slaughter cow supply in region i at t, $PFCFP_{i,t}$ is the ratio of feeder calf price over feed grain price in region i at t, $PCFP_{i,t}$ is the ratio of slaughter cow price over feed grain price in region i at t, r_t is the interest rate at t, $PSE_{i,t}$ is the producer subsidy estimate in region i at t, $BWI_{i,t}$ is the beef cow inventory in region i at t, $DWI_{i,t}$ is the dairy cow inventory in region i at t, $quarter_i$ is the vector of quarterly dummies (i=1,2,3), $Time$ is time trend variable, $D19881$ is a dummy variable and $D19881 = \begin{cases} 1 \; if \; t \geq \text{the first quarter, 1988} \\ 0 \; otherwise \end{cases}$, $D19951$ is a dummy variable and $D19951 = \begin{cases} 1 \; if \; t \geq \text{the first quarter, 1995} \\ 0 \; otherwise \end{cases}$, $\text{Pd}_{f,i,t}$ is the predictive difference in region i at t, $devPOR_{i,t}$ is risk perception deviation in region i at t, $A_{i,0}$ is the baseline risk to be estimated in region i,

$Media_{i,t}$ are media indices about BSE for cow-calf producers in region i at t, $\varepsilon_{f,i,t}$ and $\varepsilon_{i,t}$ are random errors associated with region i at t, and $\phi_{i,j}, \alpha_i, \beta_i, k_{i,j}$ are parameters to be estimated. As shown in Figure 3.6, the construction of risk perceptions and estimation procedures are the same as that based on time series data except that the parameters within the risk perception equations are regional specific.

3.3.4 Slaughter Cow Supply Model with State-Space Approach

Similar to consumer model, the producer risk perceptions about BSE can be constructed as:

$$B_t = \alpha * B_{t-1} + \beta * (k_1 * \text{Gross Media Coverage of BSE}_t + k_2 \text{'Media Subject Indices of BSE}_t + k_3 * T) \quad (3.77)$$

During the initial estimation of the state-space model, α is not estimable and the risk perceptions can't be constrained between 0 and 1. Therefore, instead, the parameters are normalized by dividing the both sides of equation 3.77 by α as:

$$B_t = B_{t-1} + r_1 * \text{Gross Media Coverage of BSE}_t + r_2 \text{'Media Subject Indices of BSE}_t + r_3 * T_t, \quad (3.78)$$

where $r_j = \beta * k_j / \alpha$. Further, the constraint $\sum \mathrm{r_j} = 0$ is imposed for identification of all parameters. This constraint is based on the fact that the number of messages about BSE risk is small and all media indices can be set to 1 in the initial period, and also based on the hypothesis that the initial BSE risk perception (or the risk perceptions before BSE outbreak) is very small and can be set to zero. Although the imposition of these restrictions is arbitrary, it guarantees the identification of parameters in both slaughter cow supply and risk perception equations. The estimation procedure is illustrated in Figure 3.7.

The model is estimated through a Bayesian method as discussed in consumer chapter. The estimated model is based on the same functional form as the predictive approach. The elasticities associated with the risk perceptions of BSE are computed as:

Short run and long run elasticity of risk perceptions about BSE:

$$EC_{S,RPBSE} = \phi_4 * \frac{\overline{RPBSE}}{\overline{X_f}}, \; EC_{L,RPBSE} = \frac{\phi_4}{(1-\phi_1)} * \frac{\overline{RPBSE}}{\overline{X_f}} \quad (3.79)$$

Figure 3.7 Slaughter Cow Supply Model and Risk Perception Estimation by State-space Approach and Time Series Data

Slaughter cow supply equation:

$$X_{f,i,t} = \phi_{i,0} + \phi_{i,1} * X_{f,i,t-1} + \phi_{i,21} * PFCFP_{i,t} + \phi_{i,22} * [PFCFP_{i,t} - E(PFCFP_{i,t})]^2 + \phi_{i,31} * PCFP_{i,t}$$
$$+ \phi_{i,32} * [PCFP_{i,t} - E(PCFP_{i,t})]^2 + \phi_{i,33} * [PFCFP_{i,t} - E(PFCFP_{i,t})][PCFP_{i,t} - E(PCFP_{i,t})]$$
$$+ \phi_{i,4} * B_t + \phi_{i,7} * r_t + \phi_{i,8} * r_{t-1} + \phi_{i,9} * PSE_t + \phi_{i,10} * PSE_{t-1} + \phi_{i,11} * BWI_{t-1} + \phi_{i,12} * BWI_{t-2}$$
$$+ \phi_{i,13} * DWI_{t-1} + \phi_{i,14} * DWI_{t-2} + \phi_{i,15}' quarter_t + \phi_{i,16} * Time + \phi_{i,17} * D19881 + \phi_{i18} * D19951$$

Risk perception equation:

$B_t = B_{t-1} + r_1 *$ Gross Media Coverage of $\text{BSE}_t + r_2'$ Media Subject Indices of $\text{BSE}_t + r_3 * T + \varphi_t$, where φ_t is a random error

State-space form:

$$SC_t = F_t(A, Y_t, \theta, B_t) + E_t \,;\, B_t = B_{t-1} + J{*}z_t + \Gamma_t$$

where: SC_t is the slaughter cow supplies. Y_t are the right hand variables in slaughter cow supply equation except B_t. B_t is the risk perception of BSE.

$z_t =$ (Gross Media Coverage of BSE_t, Media Subject Indices of BSE_t, T); A and θ are parameter vectors related with Y_t and B_t. J is parameter vector associated with Z_t. $E_t \sim N(0, \Omega), \Gamma_t \sim N(0, \sigma^2)$

3.3.5 Hypotheses to be Tested in Cow-Calf Producer Model

The hypotheses to be tested in the cow calf producer model are as follows:

1. The Social Amplification of Risk Framework (SARF). SARF suggests that cow-calf producers' risk perceptions about BSE may be affected by both quantity and quality of media messages about BSE. This hypothesis is tested by the significance of parameters on gross information index about BSE and subject indices about BSE (including BSE information addressing government, scientists, and BSE affected Canadian producers).
2. Prospective Reference Theory (PRT). PRT suggests that cow-calf producers' ex poste risk perceptions are determined by their reference risk perceptions and sampled or stated risk perceptions (Viscusi, 1989). Under the predictive difference approach, if the parameter of the lagged predictive difference of slaughter cow supplies is significant, the PRT is implied. Under the state-space approach, the parameter of lagged risk perceptions has been normalized to one and therefore, PRT is not testable.

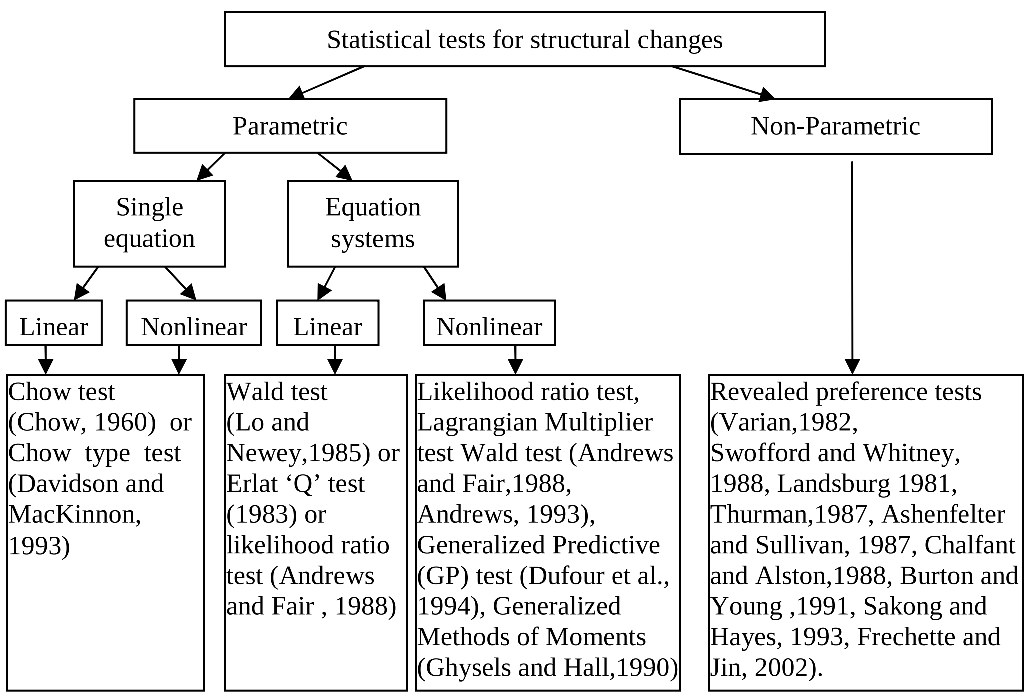
3. Self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998). This test can be done by checking the parameters on the time trend in the risk perception equations of cow-calf producers.
4. The structural break tests at the BSE outbreak in the second quarter, 2003 This hypothesis can be tested for both slaughter cow supply and beef cow inventory equations.
5. Feeder calf price ratios (over feed prices) as an indicator of future profit from calf breeding should have a negative impact on slaughter cow supplies and a positive impact on beef cow inventories. On the other hand, slaughter cow price ratios (over feed prices) as an indicator of current profits from cows culled should have a positive impact on slaughter cow supplies and a negative impact on beef cow inventories. These hypotheses can be tested by relevant parameters of feeder calf price ratios and slaughter cow price ratios.
6. Cow-calf producers will decrease their cattle operations when facing a high risk from slaughter cow prices. This hypothesis can be tested by examining the parameters of price risks related to slaughter cows in slaughter cow supply equation.
7. Producer subsidy estimates (PSE) post BSE outbreak should have a negative impact on cows culled. This is because various government policies after BSE outbreak were aimed at relieving the extra slaughter burdens and encouraging cow-calf producers to hold their cows longer.
8. Border re-opening from other countries to Canadian live cattle and the significant changes in slaughter demand will affect slaughter cow supplies in Canada. These hypotheses can be tested by the parameters of border re-opening dummies and dummies for significant changes of slaughter cow demand in slaughter cow supply equations.
9. Seasonality, time trend, the periods when Canada being a signatory to the WTO (or the elimination of Crow Rate) in 1995 and the first Canada-U.S. Free Trade Agreement (CUSTA) in 1988 will affect slaughter cow supplies. These hypotheses can be tested by the parameters of seasonal

dummies, time trend and dummies for Canada being a signatory to the WTO (or the elimination of Crow Rate) in 1995 and the first Canada-U.S. Free Trade Agreement (CUSTA) in 1988 in slaughter cow supply equations.

3.4 Parametric and Non-Parametric Tests for Structural Changes

BSE outbreaks in Canada may have led certain structural changes in consumers and producers' behaviour, which may be indicators of BSE risk perception changes for consumers and producers. Therefore, it is necessary to test structural breaks during the estimation of the consumer or producer model. Statistically, there are two ways to capture structural changes in market demand (Jun and Koo, 2003): parametric and nonparametric. The statistical tests for structural changes can be illustrated in Figure 3.8.

Figure 3.8 The Statistical Tests for Structural Changes



Parametrically, it is straightforward to test structural changes in single equations using Chow tests or Chow type tests (Davidson and MacKinnon, 1993; Chow, 1960; Dufour, 1994). However, it is not as easy to track structural changes in a system of linear or nonlinear equations. Lo and Newey (1985) have developed one Wald test to identify the structural changes within a simultaneous equation system estimated by a two-stage estimator under large samples. The simultaneous equations can be expressed as following:

$$Y = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_T \end{pmatrix} = XB + \varepsilon = \begin{pmatrix} X_1 & 0 & 0 & 0 \\ 0 & X_2 & 0 & 0 \\ 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & X_T \end{pmatrix} \begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ B_T \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_T \end{pmatrix} , \qquad (3.80)$$

where Y_i is T×1 vector; X_i is T×K matrix and B_i is K×1 vector. ε_i is T×1 vector of random errors. If there are two time periods in which the structural change happens, the equations can be expressed as:

$Y_1= XB_1+ \varepsilon_1$ for $t=(1,\dots T_1)$ with T_1 observations.

$Y_2= XB_2+ \varepsilon_2$ for $t=(T_1,\dots T)$ with $T_2=T- T_1$ observations. (3.81)

The model may be estimated by instrument Z_i. Defining $P=Z_i(Z_i'Z_i)^{-1}Z_i'$, $\hat{X}_i = P_i X_i$ and $\hat{Y}_i = P_i Y_i$ the estimation of B_i is : $\hat{B}_i = (\hat{X}_i'\hat{X}_i)^{-1}\hat{X}_i'\hat{Y}_i$ and the sample variance is $\hat{\sigma}_i^2 = (Y_i - X_i\hat{B}_i)'(Y_i - X_i\hat{B}_i)/(T_i - K)$. The Wald test for structural change can be written as:

$$W = (\hat{B}_1 - \hat{B}_2)'(\hat{\sigma}_1^2(\hat{X}_1'\hat{X}_1)^{-1} - \hat{\sigma}_2^2(\hat{X}_2'\hat{X}_2)^{-1})(\hat{B}_1 - \hat{B}_2) \sim \chi^2(K) . \qquad (3.82)$$

Erlat (1983) discussed a “Q” statistical test for structural change in a simultaneous equation system when there are insufficient degrees of freedom. Honda (1992) made some criticisms describing the approach of Erlat as incomplete in investigating the alternative hypothesis of a structural shift. The structural change tests for nonlinear simultaneous equations are few with the exception of Andrews and Fair (1988), Ghysels and Hall (1990), Andrews (1993) and Dufour et al. (1994).

Andrews and Fair (1988) proposed the likelihood ratio test, Lagrangian multiplier test and the Wald test statistic for structural breaks in a nonlinear simultaneous equation system. As they suggested, for a nonlinear dynamic simultaneous equation model:

$f_{it}(Y_t, X_t, \theta_1) = U_{it}$ for $i=1,\dots n$, $t=-T_1, \dots\dots -1$,

$f_{it}(Y_t, X_t, \theta_2) = U_{it}$ for $i=1,\dots n$, $t=1,\dots \dots T_2$ (3.83) where Y, X are observed endogenous and predetermined variables, U is unobserved error, and θ's are unknown parameter vectors. The null hypothesis without structural change is given by θ1=θ2. If the null hypothesis is rejected for every parameter in θ, a pure structural change is identified (Andrews and Fair, 1988). If there are a subset of parameters in θ constant over the entire time period, it is not a pure structural change. A likelihood ratio test can be applied for testing structural changes in a nonlinear simultaneous equation system, a likelihood ratio test constructed by $LR=2(T_1+T_2)(LogL_u-LogL_r)\sim\chi^2(k)$, where $LogL_u$ is the unrestricted log-likelihood function and $LogL_r$ is the restricted log-likelihood function calculated by the sum of log-likelihood functions for t<0 and t>0 evaluated at the separate estimates of θ1 and θ2. k is the number of parameters in θ.

The method of Andrews and Fair works for the case where minimum $(T_1,T_2)>k$. However, when minimum $(T_1,T_2)<k$, we cannot estimate two different samples to construct the likelihood ratio test. One Generalized Predictive (GP) test was suggested by Dufour et al. (1994). The GP test can be applied to the test for a structural break even near the end of the sample and is easy to calculate. The intuition behind the GP test is that if the model is stable over the entire sample, the law of motion of the random error within the prediction sub-sample should be the same as those for the estimation sub-sample. The details about the derivation of the test statistics were shown in Doufour et al.(1994). The construction of test statistic follows several steps:

(1) Estimate for the first sample T_1, obtain the parameter estimates θ_1 and the estimates of conditional covariance of random errors by the residuals in the first sample by:

$$\breve{\sigma}_{ijst} = \frac{1}{T_1} \sum_{r=-T_1+1}^{-|t-s|} \overline{\mu}_{ir}(T_1 \mid \Psi)\overline{\mu}_{j,r+|t-s|}(T_1 \mid \Psi), \qquad s \le t \tag{3.84}$$

where $\breve{\sigma}_{ijst}$ is the covariance of equation i at time s and equation j at time t, $\overline{\mu}_{ir}$ is the residual of equation i at time r, and Ψ is the information in the first sample.

After obtaining the estimates of $\breve{\sigma}_{ijst}$, construct the matrix

$$\bar{\Sigma}_{st}(T_1 \mid \Psi) = [\breve{\sigma}_{ijst}(T_1 \mid \Psi]_{i,j=1,\dots m} \text{ and } \bar{\Sigma}_{t}(T_1 \mid \Psi) = \bar{\Sigma}_{tt}(T_1 \mid \Psi) \tag{3.85}$$

(2) Use θ_1, dependent and independent variables in the second sample T_2 to compute the residuals in T_2, denoted as $\bar{\mu}_t(T_1)$, where t€T_2.

(3) Construct the covariance matrix of the second sample by:

$$\breve{\Delta}_{ij}(T_1 \mid \Psi) = [\breve{\sigma}_{ijst}(T_1 \mid \Psi)]_{s,t=1,\dots T_2} \text{ and } \bar{\Delta}(T_1 \mid \Psi) = [\bar{\Sigma}_{st}(T_1 \mid \Psi]_{s,t=1,\dots T_2} \tag{3.86}$$

(4) Compute the joint predictive test statistics for individual equations by:

$$U_j(T_1 \mid \Psi) = \bar{\mu}^j(T_1)'[\Delta_j(T_1 \mid \Psi)]^{-1}\bar{\mu}^j(T_1) \text{ where } j=1,\dots m. \tag{3.87}$$

where m is number of equations

(5) Compute the joint predictive test statistics for pooled equations by:

$$W(T_1 \mid \Psi) = \bar{\mu}(T_1)'[\Delta(T_1 \mid \Psi)]^{-1}\bar{\mu}(T_1) \text{ where } \bar{\mu}(T_1) = [\bar{\mu}_1(T_1)', \bar{\mu}_1(T_1)', \dots, \bar{\mu}_{T_2}(T_1)'] \tag{3.88}$$

When $u1,\dots u_{T2}$ are uncorrelated, the statistics of joint predictive test for individual equations and for the pooled equations are:

$$U_j(T_1 \mid \Psi) = \sum_{t=1}^{T_2}[\bar{\mu}_{jt}(T_1)/\breve{\sigma}_{jt}(T_1 \mid \Psi)]^2 \text{ where } j=1,\dots m. \tag{3.89}$$

$$W(T_1 \mid \Psi) = \sum_{t=1}^{T_2} W_t(T_1 \mid \Psi) = \sum_{t=1}^{T_2} \bar{\mu}_t(T_1)'[\bar{\Sigma}_t(T_1 \mid \Psi)]^{-1}\bar{\mu}_t(T_1) \tag{3.90}$$

The test statistics above are distributed asymptotically as $\chi^2(T_2)$ and $\chi^2(mT_2)$.

Non-parametrically, the structural break test is based on revealed preference theory (Afriat, 1967; 1973; Varian, 1982), which is seeking to what extent the observed dataset is rationalized by an underlying well-defined utility function that satisfies local nonsatiation, continuity, concavity and monotonicity. Failure to meet the requirements of the axioms of revealed preference may be interpreted as an indication of structural change in demand if consumers are assumed to be maximizing utility (Moschini, 1996). Following Varian (2006, page 2-3), the definitions of revealed preference are as follows:

1. Given some vectors of prices and chosen bundles (P^t, X^t), for t=1, …T, X^t is directly revealed preferred to a bundle X (X^tR_DX), if $P^tX^t \geq P^tX$; X^t is revealed preferred to X (X^tRX) if there is some sequence r, s, t, u, v such that $P^rX^r \geq P^rX^s$, $P^sX^s \geq P^sX^t$, ….$P^uX^u \geq P^uX$. R is the transitive closure of the relation R_D.

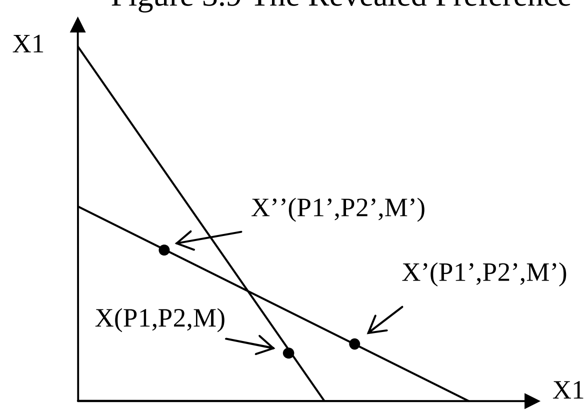
2. Weak Axiom of Revealed Preference (WEAP) is satisfied if $X^tR_DX^s$ then it is not the case that $X^sR_DX^t$, algebraically $P^tX^t \geq P^tX^s$ implies $P^sX^s < P^sX^t$

3. Strong Axiom of Revealed Preference (SARP) is satisfied If X^tRX^s *then it is not the case that* X^sRX^t*, algebraically* X^tRX^s *implies* $P^sX^s < P^sX^t$

4. If X^tRX^s *implies* $P^sX^s \leq P^sX^t$ *, Generalized Axiom of Revealed Preference (GARP) is satisfied. (Page number 2-3)*

The weak axiom of revealed preferences for a two good bundle may be illustrated by Figure 3.9. Varian (1982) developed a revealed preference test for a structural break in consumer demand. Under Varian's assumptions, consumers who can afford the same two bundles of goods at different times will not switch between them unless a structural change occurs in their preferences. The null hypothesis of structural stability is rejected if such a switch is observed anywhere in the sample. Applications of revealed preference test for structural changes include Varian (1982), Swofford and Whitney (1988), Landsburg (1981), Thurman (1987), Ashenfelter and Sullivan (1987), Chalfant and Alston (1988), Burton and Young (1991) and Sakong and Hayes (1993).

Figure 3.9 The Revealed Preference



Source: Microeconomic theory (Mas-Colell et al., 1995, section 2.F and 3.J).

where P1, P2, P1' and P2' are prices. M and M' are expenditures. X and X' are, respectively, the optimal choices of consumption for X1 and X2 under P1, P2, M and P1',P2',M'. Obviously, in Figure 3.9, X(P1, P2,M) is affordable under the budget line of X'(P1',P2',M'). The choice of X'(P1',P2',M') suggests that X'(P1',P2',M') is directly revealed preferred to X(P1,P2,M). Under the budget line of X(P1,P2,M), X'(P1',P2',M') is not affordable, therefore, X(P1,P2,M) is not directly revealed preferred to X'(P1',P2',M') and the WARP is satisfied.

However, we can find easily the violation of WARP between the point X''(P1',P2',M') and X(P1,P2,M).

Following Varian (1985), Frechette and Jin (2002) and Jun and Koo (2003), the revealed preference tests can be done by constructing an R matrix where the elements R_{st} are equal to $\frac{P_s Q_t}{P_s Q_s}$. P_s is a price vector in time s and Q_s is a quantity of demand vector in time s; $s, t \in [1, T]$. If both R_{st} and R_{ts} are less than one, the Weak Axiom of Revealed Preference (WARP) is violated. Based on the possible structural break point T_B, the R matrix can be split into before (s, t< T_B), after(s, t> T_B) and spanning sections (s> T_B >t or t> T_B >s). In the three sections, the number of violations of WARP can be computed respectively. Therefore, a table S with n individuals or households as rows and violation numbers of before, after and spanning parts of possible structural break point T_B as columns can be constructed. If there are no permanent structural changes such as the changes of preference parameters in utility functions, the three columns in table S should have the same distributions. Assuming the distribution functions of violation numbers in before, after and spanning parts of possible structural break point T_B are S_b,S_a,S_p, the null hypothesis is:

$$H_0: S_b = S_a = S_p. \tag{3.91}$$

The Friedman and Kendall tests are applied in this thesis to test the difference between the three distributions. The Friedman test is also called Friedman two-way analysis of variance by ranks (Sidney et al., 1988). The test of same distributions among three groups S_b, Sa, Sp is done by median equivalence test specified as:

$$H_0: M_b=M_a=M_p \text{ (M represents median).} \tag{3.92}$$

The test statistic is:

$$F = \left[\frac{12}{NK(K+1)} \sum_{j=1}^{K} Z_j^2 \right] - 3N(K+1) \text{ ,} \tag{3.93}$$

where N and K are, respectively, the number of rows and columns in table S. Z_j (j=1, 2, 3) is the sum of ranks in j^{th} column of table S. There are specific tables to find the significance of Friedman test, which is reported in SPSS 17.

The Kendall test applied in this thesis is also called Kendall coefficient of concordance W. Kendall's W is used to express the association of different variables with various ranking. Kendall's W is computed as:

$$W = \frac{\sum_{i=1}^{N}(\overline{Z}_i - \overline{Z})^2}{N(N^2-1)/12}, \tag{3.94}$$

where $\overline{Z}_i$ is the average of ranks of individual i or i[th] row in table S, $\overline{Z}$ is the average of ranks of all individuals or all rows in table S, and N and K are, respectively, the number of rows and columns in table S. The Kendall'W can be checked by a specific distribution table in terms of its significance, which is also reported in SPSS 17. If Friedman and Kendall tests suggest different distributions or fewer associations among before, after and spanning parts, the structural break is indicated.

The non-parametric approach is based on revealed preferences and does not require functional forms. However, the non-parametric approach is subject to some criticism according to Moschini (1996). First, the test is based on an assumption that the good is separable from other goods. Second, the revealed preference theory is based on individual choices but most of its application has been for time series data, requiring exact aggregation to be satisfied. Third, the statistical power of the revealed preference test is limited. The parametric approach may also suffer from these three critics in the real applications. Therefore, in this thesis, both parametric and nonparametric approaches for structural change tests will be applied to test BSE impacts.

3.5 Chapter Summary

This chapter discussed the theoretical and empirical methods in evaluating risk perceptions about BSE from Canadian consumers and cow-calf producers. Predictive difference approaches and state-space approaches are proposed and specified for consumer demand models and producer slaughter cow supply models to track the dynamics of risk perceptions about BSE after the BSE outbreak in Canada. The empirical models of consumers and cow-calf producers also incorporate other variables to test their impacts in consumers' and producers' decision-making. For example, the consumer models incorporate variables such as prices, per capita disposable incomes, time trend, seasonality and demographic profiles. The cow-calf producer models incorporate variables such as input and output prices, bank rates, government support, time trend, seasonality, regional difference, dummies of significant changes in slaughter cow demand after BSE outbreak, dummies of border reopening from other countries to Canadian beef and cattle after BSE outbreak and dummies at the time of entering WTO or elimination of Crow Rates. The incorporation of these variables may reduce the heterogeneity or endogeneity of error terms within consumer and cow-calf producer models. The changes in the parameters associated with these variables after BSE outbreak can also be tested. The empirical equations derived from the two approaches are the basis of estimation in the next two chapters. Further, various parametric and non-parametric statistical tests are explored which provide guidance about how to test for preference changes in consumers and cow-calf producers.

Chapter 4 Canadian Consumers' Behaviour with BSE Impacts

4.1 Introduction

BSE is a processed food safety issue for consumers and may lead to changes in their risk perceptions and purchasing behaviour. For example, there were large declines and structural changes in meat consumption in other countries where BSE was discovered, such as the U.K, Germany and Japan (Burton and Young, 1996; Verbeke and Ward, 2001; Herrmann et al., 2002; Jun and Koo, 2003; Miran and Akgungor, 2005; ElAmin, 2006). Consumers' confidence in the safety of beef consumption has decreased due to BSE discoveries (Latouche et al., 1998). At a household level, media coverage about BSE and differences in the demographic profile of consumers also played a role in their reactions to BSE discoveries (Verbeke et al., 1999a; Schroeder et al., 2007). In Canada, no decline was seen in aggregate beef consumption immediately after the first domestic BSE-infected cow was found in 2003. Nonetheless, Canadian beef consumption did decline during the fourth quarter of 2003 and the first quarter of 2005. Some studies have suggested that the BSE outbreak in May 2003 in Canada contributed to increasing risk perceptions about beef eating (Yang and Goddard, 2007) and a structural change in consumer behaviour (Peng et al., 2004; Yang and Goddard, 2007). The increase in BSE cases in Canada from 2003 to 2008 may have also led to preference changes and increasing risk perceptions by Canadian consumers. A survey done in 2006 suggested that consumers in Alberta are willing to pay more to avoid the risks associated with BSE as compared to other types of food safety issues such as genetic modified organisms and growth hormones (Steiner and Yang, 2007).

It is crucial to analyze the preference changes and the evolution of risk perceptions of Canadian households by both aggregate time series data and household panel data. In aggregate, preference changes and the evolution of risk perceptions provide important clues about how people adjust their market behaviour and their risk perceptions to BSE and other such incidents. This information can help governments to predict market demand changes and consumer risk perception changes after similar risky events. At a household level, due to different demographic profiles, Canadian households may have adjusted their meat purchase preferences in response to BSE in different ways. Further, risk perceptions about BSE in Canadian households may differ due to the fact that the households may have received different media coverage about BSE. With panel analyses of data collected on purchases and attitudes, researchers can evaluate these issues and provide policy recommendations. A further justification of using household panel data is to compensate for the limitations of consumer models based on the aggregate time series data to approximate risk perceptions. In this study only 11 quarterly observations after the BSE outbreak in May 2003 are available in the aggregate time series data to estimate risk perceptions, which may make the estimates of limited explanatory power. However, there are many more observations available in the household panel data to estimate risk perceptions, providing a remedy for the time series model and a detailed analysis of household risk perceptions that are related to their different demographic profiles and risk attitudes.

To evaluate Canadian consumers' risk perceptions about BSE and their consumption responses, five sections are included in this chapter. The second and third sections are, respectively, the demand model based on time series data and the demand model based on household panel data. The time series data are used to evaluate aggregate responses of Canadian consumers to BSE while the household panel data are used to evaluate reactions to BSE at a household level. In each of the two sections, data are described first in terms of their sources, generation procedures, distributions, and demographic profiles. The household panel data are further clustered according to different responses to survey questions (Appendix F) about beef-eating attitudes[25]. In the second part of each section, parametric and non-parametric tests are employed for structural breaks in different time periods

[25] Different techniques including cluster analysis and/or principal component analysis are applied to grouping households based on the attitude questions about beef-eating. These questions and techniques will be discussed in the sections about panel data analysis.

including the fourth quarter, 1993 (the first BSE-infected cow was found in Canada), the first quarter, 1996 (the relationship between BSE and human vCJD was announced by the U.K. government), the second quarter of 2003 (the first domestic BSE-infected cow was found in Canada), the first quarter of 2004 (one BSE-infected cow was found in the U.S.), the first quarter of 2005 (2 BSE-infected cows were found in Canada) and the third quarter of 2006 (3 BSE-infected cows were found in Canada). In the third part of each section, demand models and risk perceptions about BSE are estimated using a predictive difference approach and a state-space approach. In the last parts of the third and fourth sections, the results of hypothesis testing are reported and discussed. The fifth section of this chapter is a comparison with the previous studies about food safety. The final section provides a summary of this chapter.

4.2 Consumer Model Based on Time Series Data

4.2.1 Time Series Data

Time series data include quarterly disappearance of beef, pork, chicken and turkey, disposable income, population, consumer price indices for various types of meats collected from a variety of sources including Statistics Canada (CANSIM II, 2006) and media information about BSE collected from various media databases (Appendix A). The meat disappearance data is computed by:

$$DIS_t = TQ_t + S_{t-1} - S_t + I_t - E_t \ , \tag{4.1}$$

where DIS_t is meat disappearance at time t, TQ_t is total meat production at t, S_t is the meat stock at t, I_t is the import of meat at t and E_t is the export of meat at t.

The construction of media indices is based on the number of media messages about certain issues, which is frequently seen in the existing literature (Burton and Young, 1996; Strak, 1998; Flake and Patterson, 1999; Goddard et al., 2004; Piggott and Marsh, 2004). The news articles about BSE are collected from various databases (Appendix A). The gross BSE information index is based on a search of critical words including BSE, Mad cow disease, Bovine Spongiform Encephalopathy in the entire text of media messages with the other possible meanings of BSE[26] removed by checking the contents of the media messages. Different from the previous studies about constructing information indices, a source credibility index and a set of subject media indices about BSE are established. BSE information from different sources may have different levels of credibility for consumers and thus inspire different impacts in terms of risk perceptions (Frewer et al., 1999). To evaluate the impacts of BSE information from different sources, a national BSE information index is constructed as a count of messages about BSE from media with national coverage (e.g. The Globe and Mail, The Financial Post).

Individual subject indices for BSE information are constructed by searching specific subjects discussed in the articles, a process which reflects the *attention* of media in message making (Gerbner, 1985). Subjects such as government, scientists, and producers are frequently mentioned in BSE-related media information, which may have led to the changes in individual's risk perceptions in different ways. Before constructing subject indices for BSE information, every BSE-related news article was read carefully. The BSE information index addressing government (scientist, producer or BSE affected producer) has government (scientist, producer or BSE affected producer) as a subject in terms of BSE impacts or policies regarding BSE. The BSE information index addressing government is constructed by counting the appearance of "government"[27], "Agriculture and Agri-Food Canada"(or "AAFC"), "Canadian Food Inspection Agency"(or "CFIA") in BSE-related articles because on one hand, these words represent Canadian government or government agencies and on the other, these words are the most frequently used in all BSE-related articles addressing government. The BSE information index addressing scientists is constructed in a similar way by counting the appearance of "scientist", "expert", "veterinarian" (or

[26] The other possible meaning of BSE include Bombay Stock Exchange, Budapest Stock Exchange, Boston Stock Exchange, Breast Self Examination, Bulgarian Stock Exchange, Bulgarian software enterprise, Building Services Engineering, Baku Stock Exchange, Bahrain Stock Exchange, Biological Systems Engineering, Breast Self Exam, etc.

[27] The word "government" may also represent governments of other countries. However, every article has been read thoroughly to screen out other foreign governments in terms of BSE impacts. The same screening is done for other words such as "scientist", "farmer", etc.

“vet”), “researcher” or “professor” in BSE-related articles because these words represent scientists and are dominant in all BSE-related articles addressing scientists. The BSE information index addressing producers is constructed by counting the appearance of “farmer” in BSE-related articles because the word “farmer” represents producers and is dominant in all BSE-related articles addressing producers. The BSE information index addressing BSE affected producers is constructed by counting the joint appearance of “farmer” and “risk”[28] (or “headache”, “concern”, “threat”, “fear”, “scare”, “loss”, “devastate”, “disaster”) in BSE-related articles because these words together represent the status of BSE affected producers in most of BSE-related articles addressing BSE affected producers. The BSE information index addressing BSE affected producers is a subset of the BSE information index addressing producers. Because one article may address multiple subjects, the sum of the subject indices for BSE information can be larger than the total number of BSE-related articles. All the media indices are constructed quarterly for the time series model to be estimated for an average individual consumer.

In using the time series data, it is assumed that consumers’ behaviour can be described by that of a representative consumer and that that behaviour satisfies an exact aggregation condition (Jorgenson et al., 1980). Certain economic factors other than BSE may have also affected consumer demand such as trend, seasonality and habit formation based on meat consumption in the previous period. They are considered during model construction. Some other factors that affect consumer demand including advertising and media health coverage are not considered in the demand analysis of this chapter. These factors can have certain impacts in meat demand (Kinnucan, 1997; Verbeke et al., 1999a; Alston et al., 2000; Lomeli, 2005). However, they are not the focus of this chapter and therefore, are assumed to be not correlated with the independent variables included in the demand system. Such an assumption is also implied by many

[28]In most of BSE-related articles, word “farmer” and “risk” (or “headache”, “concern”, “threat”, “fear”, “loss”, “devastate”, “disaster”) appear together in one sentence or connected sentences to express the BSE affected status of farmers due to BSE. Every article is read carefully to screen out other meaning of the two words not concerned with farmers’ suffering from BSE.

previous studies for food safety including Burton and Young (1996), Flake and Patterson (1999), Herrmann et al. (2002) and Piggott and Marsh (2004)[29]. In all the demand models estimated in this chapter, the omitted variables are included in the random error terms and adjusted by the heteroskedasticity–consistent estimation techniques. Given the assumption of independence between omitted variables and included variables, the parameters estimated from the demand system will not be biased (Greene, 2005).

The preliminary time series data are processed by the following steps. First, the total disappearance data for beef, pork, chicken, turkey and total disposable income are divided by total population to obtain per capita disappearance and per capita disposable income data. Second, the prices of beef, pork, chicken and turkey are computed by the price indices of different types of meats normalized to the second quarter of 1981 and then multiplied by the retail prices of different types of meats in the second quarter of 1981. The real prices of beef, pork, chicken and turkey and per capita disposable income are deflated by the consumer price index for all goods. The aggregate price of meat is calculated by a Stone index, which is a weighted sum of prices of different types of meats with the weights being the expenditure shares for the meats. The underlying hypothesis of this aggregation is Composite Commodity Theorem, which states that if a group of prices move in parallel, the corresponding group of commodities can be treated as a single good (Deaton and Muellbauer, 1980b). As shown in Figure 3.2, a two-stage demand system will be estimated in this chapter with consumer risk perceptions estimated by a predictive difference approach and a state-space approach. The aggregated price will be used in the first stage of the demand system as the meat price. The variables applied for demand analysis are described in Table 4.1[30].

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[29] Burton and Young (1996) and Piggott and Marsh (2004) omitted advertising and food health information; Flake and Patterson (1999) omitted advertising; Herrmann et al. (2002) omitted food health information.

[30] The tests for stability of time series data are reported in Appendix B.

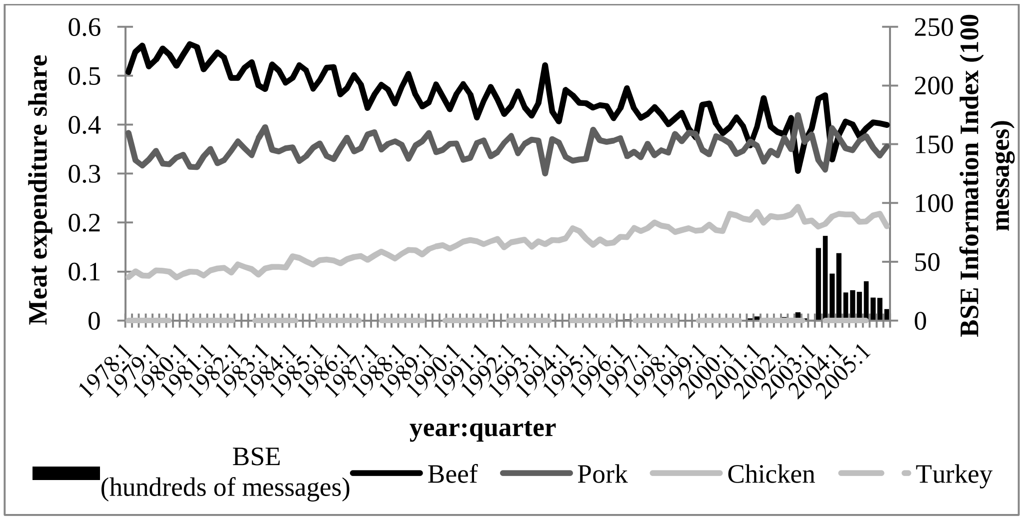
Table 4.1 Descriptive Analysis of Consumer Quarterly Time Series Data, 1978-2005

Variables	Mean	Std Dev	Minimum	Maximum
Total meat expenditure per capita (CAN $)	176.270	19.360	142.680	225.210
Per capita disposable income (CAN $)	17184.840	1026.920	15186.330	19289.490
Beef expenditure share	0.450	0.050	0.310	0.560
Pork expenditure share	0.350	0.020	0.300	0.420
Chicken expenditure share	0.160	0.040	0.090	0.230
Turkey expenditure share	0.040	0.020	0.020	0.070
Beef disappearance per capita (kg)	8.860	1.200	4.960	11.760
Pork disappearance per capita (kg)	7.840	0.710	6.250	10.160
Chicken disappearance per capita (kg)	5.670	1.280	3.510	8.200
Turkey disappearance per capita (kg)	1.060	0.480	0.490	2.050
Beef retail price (CAN $ per kg)	9.070	1.050	7.690	12.260
Pork retail price (CAN $ per kg)	7.920	0.790	6.770	10.490
Chicken retail price (CAN $ per kg)	4.800	0.290	4.170	5.530
Turkey retail price (CAN $ per kg)	6.190	0.590	5.160	8.150
BSE media index	372.000	1210.000	1.000	7206.000
BSE information from national media	155.000	508.000	1.000	3073.000
BSE information from local media	218.000	705.000	1.000	4134.000
BSE information from print media	369.000	1201.000	1.000	7160.000
BSE information addressing government	304.000	918.000	1.000	5215.000
BSE information addressing scientists	88.000	235.000	1.000	1626.000
BSE information addressing producers	147.000	447.000	1.000	2422.000
BSE information addressing BSE affected producers	102.000	306.000	1.000	1611.000

The descriptive analysis shows that on average, beef and pork consumption account for 80% of total meat consumed although beef and pork prices are higher than chicken and turkey prices. The BSE information from local media is more than that from national media. The BSE information from print media is dominant in total BSE information. The BSE information addressing government is much more than the BSE information addressing other subjects. The historical trends in BSE media coverage and meat expenditure shares are shown by Figure 4.1.[31]:

[31] The individual meat disappearances and prices are also reported in Appendix B.

Figure 4.1 Canadian Meat Expenditure Shares and BSE Media Coverage in Canada



Source: Statistics Canada database CANSIM II and various media databases (Appendix A).

Historically, the beef expenditure share in total meat expenditure is fluctuating downward while the chicken expenditure share is fluctuating upward. The pork and turkey expenditure shares are relatively stable over time. Similar trends can be found in the disappearance of beef, pork, chicken and turkey (Appendix B). A close look at the data in 2003 revealed that the beef expenditure share increased from the first quarter to the second quarter of 2003 and then, decreased from the second quarter of 2003 to the fourth quarter of 2003 and recovered again, which might imply that BSE impacts were temporary. The BSE media coverage peaked in the second quarter of 2003 and in the first quarter of 2004. A correlation analysis suggested that the gross BSE information had a negative correlation (ρ=-0.28) with the beef expenditure share but had a positive correlation with chicken expenditure share (ρ=0.38)[32], implying that BSE media coverage might have encouraged the substitution of chicken for beef. The preference changes in meat consumption due to BSE are therefore tested in the following two sections.

[32] The BSE media coverage has small correlations with pork expenditure share (ρ=-0.013) and turkey expenditure share (ρ=-0.004). Therefore, BSE information might not have big impacts over pork and turkey consumption.

4.2.2 Revealed Preference and Non-Parametric Structural Break Test

The BSE outbreaks may have led to structural breaks in consumer preferences, which require certain statistical tests. To have a robust result, both parametric and non-parametric structural break tests are employed. The non-parametric structural break test is based on revealed preference theory (Afriat, 1967; 1973; Varian, 1982). As discussed in Chapter 3 (section 3.4), the non-parametric structural break test is based on the numbers of violations of revealed preference before and after the possible break point. However, a revealed preference analysis suggests that there are no preference violations in the quarterly time series data of consumers and therefore, Canadian consumers are rational and maximize their utilities. Because the non-parametric structural break test is based on the changes of violation times of revealed preference before and after the possible break points, the non-parametric structural break test can't be applied here for the time series data.

4.2.3 Demand Model with Predictive Difference Approach

The demand model is first estimated based on time series data and using a predictive difference approach to establish changes in risk perceptions. During model estimation, a parametric structural break test is employed to examine the BSE impacts on consumer behaviour.

4.2.3.1 Parametric Structural Break Test

In terms of parametric structural break tests, a generalized predictive (GP) test (Dufour et al., 1994) is applied for the same structural break points as in the non-parametric structural break test. The empirical model estimated is a two-stage demand system (doublelog-TransLog) as specified in Chapter 3 (Figure 3.2). The results of the structural break tests are shown in Table 4.2.

Table 4.2 Results of Parametric Structural Break Test Based on Quarterly Time Series Data, 1978-2005

	P-values of GP test[a]				
Possible structural break point	The first quarter, 1994	The first quarter, 1996	The second quarter, 2003	The first quarter, 2004	The first quarter, 2005
Beef equation	0.001	0.001	0.001	0.013	0.051
Pork equation	0.001	0.001	0.002	0.006	0.042
Chicken equation	0.001	0.001	0.001	0.001	0.034
Total expenditure equation	0.001	0.001	0.004	0.010	0.045
Equations jointly	0.001	0.001	0.246	0.286	0.472

a: GP test is discussed in Chapter 3.

The results suggest that there are structural breaks in beef, pork, chicken and total expenditure equations from the two-stage meat demand system at the first quarter, 1994, the first quarter, 1996, the second quarter, 2003, the first quarter, 2004 and the first quarter, 2005. In terms of the joint significance, the first quarter 1994, the first quarter 1996 present significant structural breaks while the second quarter 2003, the first quarter 2004 and the first quarter 2005 don't imply structural breaks, suggesting that the first case of BSE found in Canada and the announcement of a possible relationship between BSE and human vCJD created a larger impact on meat demand by altering consumer preferences for meats as compared to the other structural break points. The structural break tests provide empirical evidence about consumer preference changes due to BSE but are not capable of measuring the preference changes due to BSE as reflected by the dynamics of consumer risk perceptions. Also, other factors may have had impacts on preference changes as well. These issues will be resolved in the following section.

4.2.3.2 Model Estimation

The models shown in Figure 3.2 are estimated by Full Information Maximum Likelihood (FIML) based on quarterly time series data. The economic properties implied by indirect utility functions such as symmetry ($c_{i,j} = c_{j,i}$), zero homogeneity ($\sum_{i=1}^{4} c_{i,j} + d_i = 0$) are imposed on the demand system (second stage) due to a high multicollinearity (condition number among variable=143>30) and failure of convergence of the demand system without these properties. Homothetic separability ($\sum_{j=1}^{4} c_{i,j} = 0$) is also imposed as a maintained requirement of a two-stage demand system (Green, 1976). The demand model is estimated over the period before BSE (the first quarter, 1978- the first quarter , 2003) and the entire period (the first quarter, 1978- the fourth quarter, 2005) given the insufficient observations to estimate a demand model after BSE outbreak in 2003. As indicated in the structural break test, there are certain structural changes in consumer demand after BSE outbreak in 2003. Therefore, the demand model estimated over the entire period has incorporated dummies for each quarter after BSE outbreak in the second quarter, 2003 (for example: $D20033 = \begin{cases} 1 \; if \; year = 2003 \; and \; quarter = 3 \\ 0 \; otherwise \end{cases}$)[33]. These dummies, however, are not significant and are removed based on likelihood ratio tests to improve model fit. The estimation results are reported in Table C.1 in Appendix C. The elasticities[34] from two time periods are reported in Table 4.3.

Among the four types of meats, turkey is the most elastic. The own-price elasticities of beef, pork and chicken are quite similar. All own-price elasticities are significant. Comparing the elasticity results based on the period from the first quarter 1978 to the first quarter 2003 and those based on the period from the first quarter 1978 to the fourth quarter 2005, beef and pork demand are more elastic before BSE-infected cow was found in May, 2003 while turkey demand is less elastic. Economically, these changes are not significant. According to the results of the Allen-Uzawa elasticity of substitution, the substitution between beef and chicken is lower before BSE as compared to that measured over the whole time period. People may tend to substitute more beef for chicken after BSE although the magnitude of change is very small.

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[33] We have also incorporated the dummies for the structural break points before BSE outbreak in 2003 but these dummies are not significant and removed by likelihood ratio tests.

[34] Please refer to Appendix D for the properties of a doublelog-TransLog demand system and the computation of conditional and unconditional elasticities.

The elasticities of risk perceptions related to BSE are also computed for beef, pork, chicken and turkey. The results suggest that the risk perceptions associated with BSE have negative impacts on beef and pork consumption but positive effects on chicken and turkey consumption, suggesting substitution of beef for chicken or turkey due to BSE.

Table 4.3 Elasticities from Demand Model Based on Time Series Data and Predictive Difference Approach

Elasticity[a]	Quantity v.s. price	Time period	
		The first quarter, 1978- the first quarter, 2003	The first quarter, 1978- the fourth quarter, 2005
Elasticities across two stages	Beef-Beef	-0.500 (-7.500) ***	-0.450 (-6.710) ***
	Pork-Pork	-0.510 (-6.940) ***	-0.470 (-6.380) ***
	Chicken-Chicken	-0.480 (-5.280) ***	-0.480 (-5.620) ***
	Turkey-Turkey	-0.810 (-5.340) ***	-0.820 (-5.30) ***
	Beef-Pork	0.130 (2.50) ***	0.110 (2.190) **
	Beef-Chicken	0.020 (0.91)	0.030 (1.220)
	Beef-Turkey	0.170 (2.500) ***	0.150 (2.190) **
	Pork-Beef	0.010 (0.120)	0.010 (0.570)
	Pork-Chicken	0.070 (0.910)	0.090 (1.220)
	Pork-Turkey	0.010 (0.120)	0.030 (0.570)
	Chicken-Beef	0.010 (1.200)	0.010 (1.200)
	Chicken-Pork	0.010 (0.430)	0.010 (0.900)
	Chicken-Turkey	0.070 (2.350) ***	0.070 (2.300) **
	Turkey-Beef	0.150 (1.200)	0.150 (1.200)
	Turkey-Pork	0.050 (0.430)	0.100 (0.900)
	Turkey-Chicken	0.280 (2.350) ***	0.280 (2.300) **
Allen-Uzawa elasticity of substitution	Beef-Beef	-0.740 (-7.600) ***	-0.700 (-6.770) ***
	Pork-Pork	-1.110	-1.030

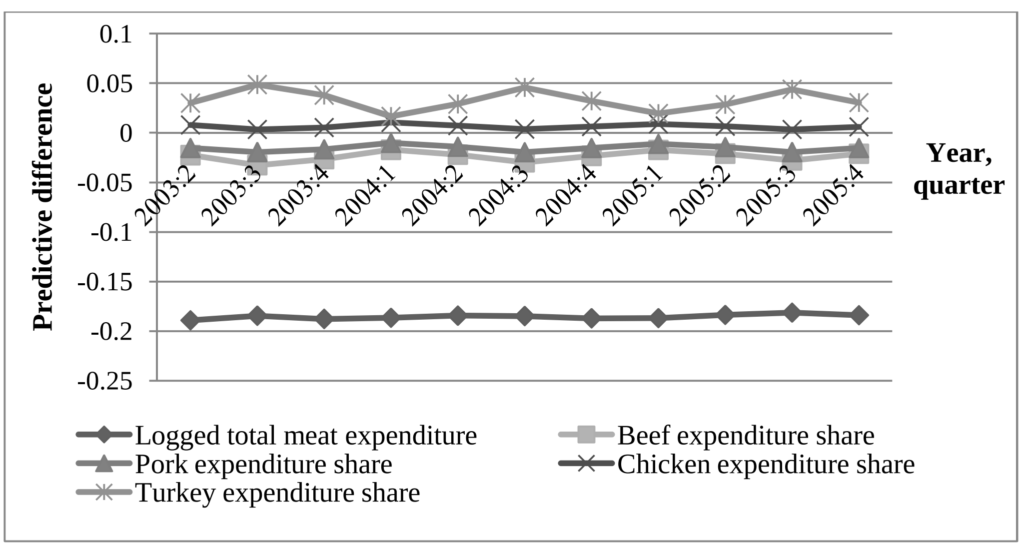
		(-6.640) ***	(-6.160) ***
	Chicken-Chicken	-2.840 (-4.950) ***	-2.790 (-5.340) ***
	Beef-Pork	0.690 (7.080) ***	0.620 (5.980) ***
	Beef-Chicken	0.480 (3.680) ***	0.490 (3.840) ***
	Pork-Chicken	0.360 (2.200) **	0.390 (2.520) ***
Risk perception elasticities across two stages[b]	Beef-risk perception	-0.220 (18.990) *	
	Pork-risk perception	-0.001 (5.490)	
	Chicken-risk perception	0.007 (3.980)	
	Turkey-risk perception	0.007 (7.240) *	

a The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels. The elasticities estimated are short-run elasticities because the demand model incorporates the habit formation.

b. The risk perception is approximated by the predictive difference based on the data during the period from the first quarter, 1978 to the first quarter, 2003 and the data during the period from the first quarter, 1978 to the fourth quarter, 2005.

The predictive differences based on time series data are reported in Figure 4.2. The predictive differences from the second quarter 2003 to the fourth quarter 2005 for logged total meat expenditure, beef and pork expenditure shares are negative, while the predictive differences for chicken and turkey expenditure shares are positive.

Figure 4.2 Predictive Differences Based on Time Series Data



The estimation results for the risk perception equations are reported in Table 4.4.

Table 4.4 Results from BSE Risk Perception Equation Based on Time Series Data from The Second Quarter 2003 to The Fourth Quarter 2005 and Predictive Difference Approach

Dependent variable: risk perception deviations approximated by predictive difference approach[a]	
Independent variables	Parameter Estimates
Constant	0.049 (12.100) ***
Gross BSE information	0.001 (2.790) ***
BSE information addressing government	-0.001 (-3.130) ***
BSE information addressing scientists	-0.001 (-3.860) ***
BSE information addressing BSE affected producers	0.001 (0.320)
Lagged risk perception	0.540 (0.380)
R-squared	0.790

a: All BSE information indices are of 100 messages. National media information of BSE is removed due to the high multicollinearity among various media information indices (condition number=59>30). Time trend is also removed due to failure of convergence. The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels.

In the time series model, there are only 11 observations to estimate the risk perception equation, limiting the explanatory power of the results. However, such a limitation will be remedied by the household panel data model, in which many more observations available to estimate risk perception equations. As shown in Table 4.4, BSE information has a positive impact on risk perceptions. The more information about BSE, the more risky people feel about beef consumption. The BSE information addressing government or scientists has significantly negative impacts on risk perceptions, implying risk attenuation by media information focusing on government or scientists. The BSE information addressing BSE affected producers due to BSE has a positive impact on risk perceptions but the effect is not significant. The fact that both the quantity (gross BSE information) and the quality of BSE information (information sources, information subjects, etc.) affect consumer risk perceptions implies a Social Amplification of Risk Framework. However, lagged risk perceptions don’t play a significant role in the risk perception equation, suggesting that based on time series data, consumers may not follow an adaptive approach in their risk perception adjustments. The significance of the constant in the risk perception equation also implies that the baseline risk perceptions have a significant impact on risk perceptions. The estimated risk perceptions over time are drawn Figure 4.3.

Figure 4.3 Risk Perceptions of BSE (RPBSE) Based on Time Series Data of Consumer Demand and Predictive Difference Approach

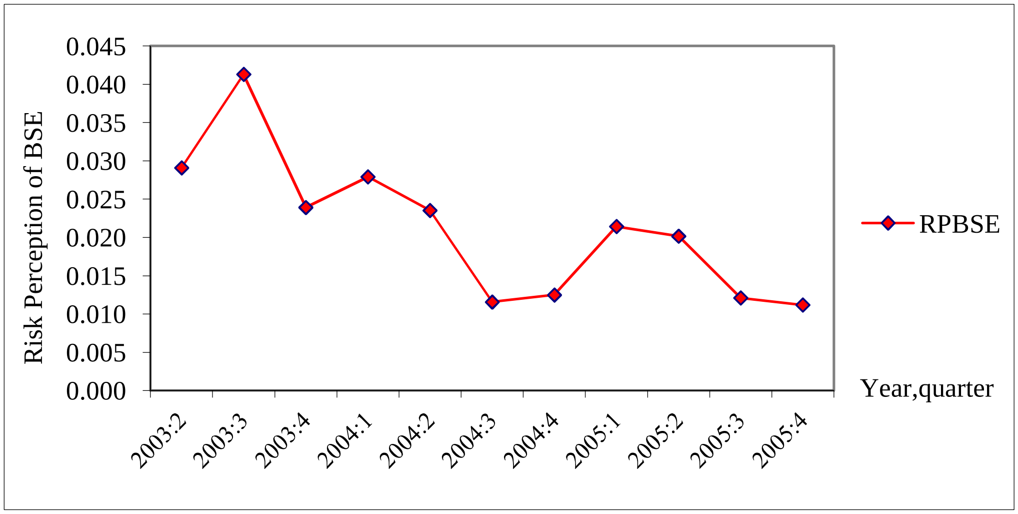


Figure 4.3 shows that for the period: the second quarter, 2003-the fourth quarter, 2005, Canadian consumers on average had their highest risk perceptions about BSE in the second quarter of 2003. The finding of a BSE-infected cow in the U.S. in the first quarter of 2004 also contributed to an increase in BSE-related risk perceptions in Canada. A similar increase in BSE-related risk perceptions was observed in the first quarter of 2005, when two cases of BSE-infected cows were found in Canada. Although Canadian households on average had increasing risk perceptions about BSE corresponding to the discoveries of new BSE cases, the magnitudes of the increases became smaller over time, suggesting diminishing effects of BSE discoveries.

4.2.4 Demand Model with State-Space Approach

The demand model estimated through the state-space approach is shown in Table C.2 in Appendix C. Three state-space models are estimated with different assumptions about the time periods when risk perception changes. The first model (model 1) assumed that the risk perceptions associated with BSE started rising when the first BSE-infected cow was found in Canada in the fourth quarter of 1993. The second model (model 2) assumed that the risk perceptions about BSE started rising after the announcement of the possible relationship between mad cow disease and human vCJD in the first quarter of 1996. The third model (model 3) assumed that the risk perceptions about BSE started rising after the first domestic BSE-infected cow was found in Alberta in the second quarter of 2003. As shown by the parameters and associated significance levels, lagged disappearance has a significant impact on beef expenditure share and total meat expenditure, suggesting habit formation in beef demand and total meat demand. The quarterly dummies and time trend have significant impacts in most of the expenditure share equations, suggesting that seasonality and structural changes in meat consumption are important trends. Risk perceptions of BSE have a significant impact on beef expenditure shares, suggesting a possible structural change in beef demand due to BSE. It has been shown that many parameters within the state-space models are not very significant, which may be due to correlations among the parameters in the risk perception equation and the demand equations. The estimated elasticities are reported in Table 4.5.

Table 4.5 Elasticities from Demand Model Based on Time Series Data and State-Space Approach

Elasticities	Quantity v.s. price or risk perception	Parameters		
		Model 1	Model 2	Model 3
Elasticities across two stages	Beef-Beef	-0.880 (12.130) ***	-0.760 (10.290) ***	-0.810 (7.780) ***
	Beef-Pork	0.100 (2.020) **	0.190 (3.950) ***	0.140 (1.610)
	Beef-Chicken	0.040 (1.080)	0.080 (2.080) **	0.050 (1.100)
	Beef-Turkey	0.030 (0.770)	0.030 (0.980)	0.030 (0.770)
	Pork-Beef	0.120 (2.000) **	0.240 (3.860) ***	0.180 (1.600)
	Pork-Pork	-0.900 (13.080) ***	-0.820 (11.650) ***	-0.860 (9.460) ***
	Pork-Chicken	0.050 (1.130)	0.090 (1.960) *	0.070 (1.240)

	Pork-Turkey	0.030 (0.650)	0.040 (0.860)	0.030 (0.710)
	Chicken-Beef	0.120 (1.060)	0.220 (2.020) **	0.150 (1.090)
	Chicken-Pork	0.120 (1.240)	0.210 (2.350) ***	0.160 (1.360)
	Chicken-Chicken	-0.950 (6.850) ***	-0.900 (6.620) ***	-0.920 (6.610) ***
	Chicken-Turkey	0.020 (0.160)	0.030 (0.270)	0.020 (0.220)
	Turkey-Beef	0.330 (0.770)	0.410 (0.980)	0.330 (0.770)
	Turkey-Pork	0.280 (0.650)	0.360 (0.850)	0.310 (0.700)
	Turkey-Chicken	0.070 (0.160)	0.110 (0.270)	0.090 (0.220)
	Turkey-Turkey	-1.400 (1.830) *	-1.340 (1.880) *	-1.340 (1.800) *
Allen-Uzawa Elasticity of substitution	Beef-Beef	-1.230 (9.410) ***	-1.230 (9.980) ***	-1.220 (9.710) ***
	Beef-Pork	0.990 (10.070) ***	1.000 (10.690) ***	1.000 (10.570) ***
	Beef-Chicken	0.980 (4.540) ***	0.960 (4.560) ***	0.940 (4.420) ***
	Beef-turkey	1.450 (1.550)	1.380 (1.570)	1.330 (1.440)
	Pork-Beef	0.970 (9.050) ***	0.980 (9.510) ***	0.980 (9.280) ***
	Pork-Pork	-1.860 (10.720) ***	-1.880 (10.880) ***	-1.870 (10.310) ***
	Pork-Chicken	1.030 (3.710) ***	1.050 (3.800) ***	1.030 (3.660) ***
	Pork-Turkey	1.490 (1.280)	1.440 (1.290)	1.460 (1.230)
	Chicken-Beef	0.960 (4.120) ***	0.930 (4.120) ***	0.930 (4.010) ***
	Chicken-Pork	1.030 (5.820) ***	1.040 (5.920) ***	1.030 (5.700) ***
	Chicken-Chicken	-5.300 (6.020) ***	-5.250 (6.170) ***	-5.200 (6.040) ***
	Chicken-Turkey	1.150 (0.400)	1.230 (0.470)	1.180 (0.440)

	Turkey-beef	1.450 (1.550)	1.380 (1.570)	1.330 (1.440)
	Turkey-pork	1.510 (1.250)	1.450 (1.260)	1.480 (1.200)
	Turkey-Chicken	1.170 (0.410)	1.250 (0.480)	1.190 (0.450)
	Turkey-Turkey	-36.940 (1.790) *	-35.960 (1.960) *	-35.320 (1.770) *
Risk perception elasticities across two stages	Beef-risk perception	-0.030 (1.020)	-0.020 (1.080)	-0.001 (0.090)
	Pork-risk perception	0.020 (0.600)	0.020 (0.900)	0.010 (1.490)
	Chicken-risk perception	0.080 (1.790) *	0.070 (1.830) *	0.020 (1.780) *
	Turkey-risk perception	-0.130 (0.270)	-0.090 (0.240)	-0.050 (0.300)

a: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels.

The price elasticities from the three models are very similar. The own-price elasticities are all significant with turkey having the largest own-price elasticities, which is similar to that in the predictive difference approach. Most of the cross-price elasticities are not statistically significant except for that between beef and pork. The low significance of price elasticities may be due to the multicollinearity (condition number=170>30) among different variables in the models. The Allen-Uzawa elasticities of substitution show a significant substitution between beef and pork and between beef and chicken.

In terms of risk perception elasticities, beef demand responds negatively to BSE risk perceptions while other meat demands respond positively to BSE risk perceptions, implying substitution of beef by other meats due to BSE. The risk perception elasticities of chicken are significant, suggesting a significant substitution of beef consumption by chicken. The results of the risk perception elasticities by state-space approach are somewhat different than those from the predictive difference approach, where a significant substitution of beef by turkey was found. The estimates from the risk perception equation are reported in Table 4.6.

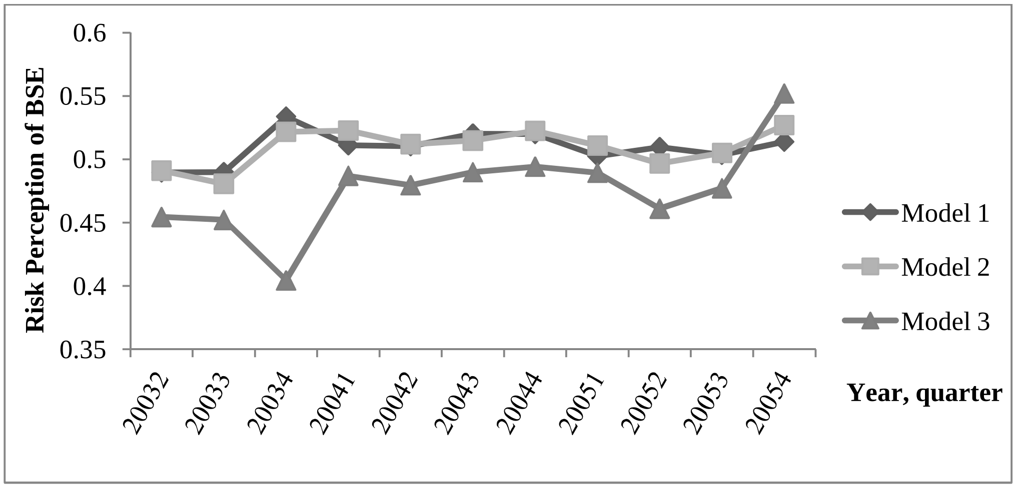
Table 4.6 Results from BSE Risk Perception Equation Based on Time Series Data and State-Space Approach

Dependent variable: risk perception estimated by state-space approach			
Independent variables	Parameter Estimates		
	Model 1	Model 2	Model 3
Gross BSE information[a]	0.015 (9.290) ***	0.048 (21.790) ***	0.050 (22.250) ***
BSE information from national media	0.022 (11.550) ***	0.049 (22.170) ***	0.050 (22.410) ***
BSE information index addressing government	0.009 (4.900) ***	0.049 (21.560) ***	0.050 (22.260) ***
BSE information index addressing scientists	0.032 (13.720) ***	0.050 (22.480) ***	0.050 (22.260) ***
BSE information addressing BSE affected producers	0.031 (15.530) ***	0.050 (22.090) ***	0.050 (22.340) ***
Time	-0.051 (-16.980) ***	-0.236 (-46.980) ***	-0.239 (-47.620) ***
DIC	-478.289	-516.494	-833.585

a: All the media indices are of 100 messages. The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels.

DIC represents the Deviance Information Criterion, which is applied to test for model selection. The more negative the DIC, the better the model fit (Spiegelhalter et al., 2002). The DIC measures suggest that model 3 fits the data best among the three models. According to the estimation results for model 3, all types of media indices have significant effects on risk perceptions about BSE. The time trend variable has a negative effect on risk perceptions for BSE, suggesting a reference point effect where people adjust their risk perceptions based on their initial perceived risk (Kask and Maani, 1992; Liu et al., 1998). All media indices in model 3 have significantly positive effects on consumer risk perceptions, suggesting that both the quantity and quality of information have amplified the risk perceptions associated with BSE. This is different from the estimations based on the predictive difference approach, where the information addressing government or scientists played an attenuation role in risk perceptions. Nevertheless, both the predictive difference approach and state-space approach (model 2 and model 3) suggest that the gross media information on BSE has enlarged risk perceptions of BSE, leading to a decline in beef consumption. Further, both of the approaches provide empirical support for the Social Amplification of Risk Framework. The Prospective Reference Theory cannot be tested in the state-space approach due to identification problems. The estimated risk perceptions of BSE by model 1, model 2 and model 3 are summarized in Figure 4.4.

Figure 4.4 Risk Perception of BSE Based on Time Series Data and State-Space Approach



The risk perceptions estimated from the state-space model are constrained to fall between 0 and 1. From the three models estimated, the risk perceptions associated with BSE fluctuated over time with a large increase in either the fourth quarter of 2003 or the first quarter of 2004, suggesting a lagged impact of the BSE discovery in the second quarter of 2003 in Canada and an impact of the BSE discovery in the first quarter of 2004 in the U.S. Risk perceptions related to BSE remain at higher levels than existed in the second quarter of 2003 since early 2004, suggesting that the discovery of more BSE-infected cows may have exacerbated consumer perceived risk about the existence of BSE in the beef industry.

4.2.5 Tests for Hypotheses

The hypotheses tested are as follows:

1. The Social Amplification of Risk Framework (SARF). As shown in Table 3.4 and 3.6, results from both the predictive difference approach and state-

space approach illustrate that both the gross media index and at least one of the content information indices are statistically significant. Therefore, SARF has some support using these estimation methods.

2. Prospective Reference Theory (PRT). Given the results in Table 3.4, the parameter on the lagged risk perception is not statistically significant and therefore, the PRT is not supported. In the state-space approach, the PRT cannot be tested due to identification problems. Therefore, using this indirect test it appears that the PRT is not supported by the time series data.
3. Self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998). It cannot be tested under the predictive difference approach due to failure of convergence when incorporating a time trend variable in risk perception equation. However, the significantly negative parameter on the time trend variable in the risk perception equation in the state-space approach suggests that the self-adjustment of risk perceptions over time is a realistic explanation of behaviour. The negative parameter further implies that consumers tend to go back to their initial perceived risks.
4. "Sympathy" or "altruism" of Canadian consumers to the plight of Canadian cattle producers. Both the predictive difference approach and state-space approach show that the BSE information addressing BSE affected producers has a positive impact in risk perceptions and led to a decline in beef consumption. Therefore, the "sympathy" or "altruism" hypothesis is not supported by the time series data.
5. Structural break tests at the time period when BSE media coverage was high in Canada (the first quarter, 1994 and the first quarter, 1996) and at the time period when domestic BSE was discovered in Canada (the second quarter, 2003, the first quarter, 2004 and the first quarter, 2005). Parametrically, a generalized predictive test (Dufour et al., 1994) is applied to the two-stage demand system to check if the parameters are stable. As shown in Table 3.2, there are structural breaks at both the time periods when BSE was frequently reported in Canada and at the time periods when domestic BSE was discovered in Canada. Further, there are

structural breaks in the first quarter, 2004 and first quarter, 2005 corresponding to the time periods when several subsequent BSE-infected cows were found in Canada. The non-parametric test is not applicable for the time series data.

6. Seasonality, time trend and habit formation. As shown by the significance of parameters associated with lagged meat consumption, quarterly dummy variables and the time trend variable in Tables C.1 and C.2, habit formation, seasonality and trend have significant effects on consumer expenditure shares and total meat expenditure.

4.3 Consumer Model Based on Household Panel Data

4.3.1 Household Panel Data

4.3.1.1 Demographic Profiles

The data used for this study are collected from the Nielsen Homescan™ panel. The household panel contains approximately 9300 households per year for which purchase and demographic data are collected. For our analysis, 5000 households who were in the panel over the period 2002- 2007[35] were selected to participate in a survey in January 2008 (Appendix F). Individual trust in different organizations, risk attitudes and risk perceptions about food consumption are collected in the consumer survey.

Since the purpose of the analysis was to examine the effects of BSE on risk attitudes/perceptions and on behaviour it was critical to have purchase data from before the first domestic case of BSE in the country (May 2003). The analysis that follows is for the 4076 households[36] in the sample from 2002 to 2007 who also completed the survey. Table 4.7 shows the demographic profile of the Nielsen Homescan™ panel in 2006, the panel used in this study in 2006, and all Canadian households from the 2006 Census including region, language, household size, age and presence of children, household head age, household head education, income and origin.

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[35] The data is up to July, 2008 and the demand model systems are estimated over the annual data from 2002 to 2007.

[36] There are 4090 households shown in the survey. However, the meat purchase information of 14 households are not available and therefore, they are omitted.

Table 4.7 Frequency Analysis of Nielsen Homescan™ Data, 2006

Demographic Variables	Categories	Nielsen Homescan™ Panel 2006		Panel Used in this study 2006[a]		Canadian household distributions (2006 census)[b]		Pearson Chi-squared test statistics H0: Same distributions		
		(1)		(2)		(3)				
		Freq.	%	Freq.	%	Freq.	%	(1) v.s. (2)	(2) v.s. (3)	(1) v.s. (3)
Region	Maritimes	1123	12.300	537	13.200	725935	5.900			
	Quebec	2243	24.600	982	24.100	3189345	26.100			
	Ontario	2850	31.200	1063	26.100	4555025	37.300			
	Man/Sask.	993	10.900	433	10.600	835925	6.800	86 ***	616 ***	104 ***
	Alberta	979	10.700	528	13.000	1256195	10.300			
	BC	943	10.300	533	13.100	1643150	13.500			
	Total	9131	100. 000	4076	100. 000	12205575	100. 000			
Language	English	7042	77.100	3245	79.600	22898065	76.200	14 ***	26 ***	4 *
	French	2089	22.900	831	20.400	7139130	23.800			
	Total	9131	100. 000	4076	100. 000	30037195	100. 000			
Household size	Single Member	2214	24.200	1133	27.800	3327050	26.800			
	Two Members	3658	40.100	1754	43.000	4175145	33.600			
	Three Members	1244	13.600	582	14.300	1978555	15.900	140 ***	272 ***	181 ***
	Four Members	1317	14.400	450	11.000	1868765	15.000			
	Five - Nine Plus	698	7.600	157	3.900	1087955	8.700			
	Total	9131	100. 000	4076	100. 000	12437470	100. 000			
Age and presence of children	Under 6 only	346	3.800	81	2. 000	900165	7.400			
	Age 6 to 12 only	610	6.700	149	3.700	1380275	11.300			
	Age 13 to 17 only	696	7.600	270	6.600					
	Under 6 and age 6 to 12	322	3.500	144	3.500	553425	4.500			
	Under 6 and age 13 to 17	147	1.600	119	2.900					
	Age 6 to 12 and age 13 to 17	399	4.400	181	4.400	387230	3.200	347 ***	344 ***	325 ***
	Under 6, age 6 to 12 and age 13 to 17	50	0.500	43	1.100	32485	.300			
	Some under 18 and some above 18					607905	4.900			
	No children under 18	6561	71.900	3086	75.700	8362405	68.400			
	Total	9131	100. 000	4076	100. 000	12223890	100. 000			
Age of household head	18-34	710	7.800	66	1.600	27282019	86.300			
	35-44	2077	22.700	630	15.500					
	45-54	2241	24.500	1056	25.900			446 ***	109 ***	693 ***
	55-64	1987	21.800	1039	25.500					
	65+	2116	23.200	1285	31.500	4330981	13.700			
	Total	9131	100. 000	4076	100. 000	31613000	100. 000			
Income	< $20,000	936	10.300	394	9.700	1899075	15.300	75 ***	404 ***	413 ***
	$20,000-	1146	12.600	571	14.000	1301050	10.500			

	$29,999									
	$30,000-$39,999	1245	13.600	638	15.700	1364980	11.000			
	$40,000-$49,999	1066	11.700	591	14.500	1234765	9.900			
	$50,000-$69,999	1857	20.300	763	18.700	2077250	16.700			
	$70,000+	2881	31.600	1119	27.500	4560345	36.700			
	Total	9131	100. 000	4076	100. 000	12437465	100. 000			
	NOT high school educated	1291	14.100	588	14.400					
	High school educated	1581	17.300	767	18.800					
Education level of household head	Some college or tech	1221	13.400	607	14.900	13396370	77.100	21 ***	13 ***	2
	College or tech graduates	2115	23.200	899	22.100					
	Some university	881	9.600	378	9.300					
	University graduates	2042	22.400	837	20.500	3985745	22.900			
	Total	9131	100. 000	4076	100. 000	17382115	100. 000			
	Urban	5632	61.700	2451	60.100	25350743	80.200			
Origin	Rural	3499	38.300	1625	39.900	6262154	19.800	4 *	103 ***	197 ***
	Total population	9131	100. 000	4076	100. 000	31612897	100. 000			

a: 14 households don't show their meat purchase information and therefore, are removed. "*,**,***" represent 95%, 97.5% and 99% level of significance respectively.
b: The distributions of Canadian households profiles are computed based on data from Statistics Canada, 2006 Census (Appendix B)

Canadian household profiles from the 2006 Census are different from the distributions of study panel and the whole Nielsen Homescan™ panel in 2006. For example, in the 2006 Canadian Census, the number of households from Quebec and Ontario are a larger percentage of the total number of Canadian households (63.4%) as compared to the study panel (50.2%) and to the whole Nielsen Homescan™ panel (55.8%). In the Census, households with single or two members are a lower percentage of Canadian households (60.4%) as compared with the study panel (70.8%) and the whole Nielsen Homescan™ panel (64.3%). In the Census, households with some children under the age of 18 are a higher percentage of Canadian households (31.6%) as compared to the study panel (24.3%) and the whole Nielsen Homescan™ panel (28.1%). In the Census, households with age of household head lower than 65 are a higher percentage of Canadian households (86.3%) as compared to the study panel (68.5%) and the whole Nielsen Homescan™ panel (76.8%). In the Census, more households have annual incomes less than $20,000 (15.3%) as compared to the study panel (9.7%) and the whole Nielsen Homescan™ panel (10.3%). From the Census, more households originate from "Urban" areas (80.2%) as compared to the study panel (60.1%) and the whole Nielsen Homescan™ panel (61.7%). Therefore, in this study the households examined have older heads, are more rural, have higher incomes and fewer children than the Canadian population as a whole. The whole Nielsen Homescan™ panel is managed to ensure representative demographics on an annual basis. In selecting a time series for certain participants for the study panel it is possible that the households remaining in the sample are older and may not be representative of the Canadian population. However, it is still possible to match the demographic profiles from Nielson panel to certain portion of Canadian households by the comparison of 2006 Census and Nielson panel data.

4.3.1.2 Meat Purchases

In terms of purchase frequencies for the different types of meats (in percentage terms), beef, chicken and pork are dominant in household purchases for the whole Nielsen Homescan™ panel and for the study panel during the period 2002-2007 (Table 4.8).

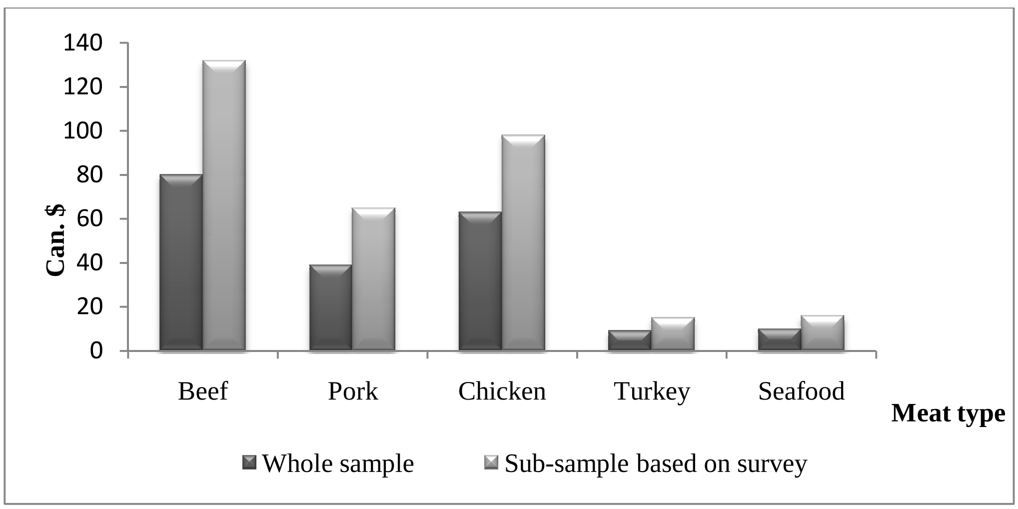
Table 4.8 The Frequencies of Meat Purchases

Meat type	Purchase frequencies (%)[a]		Average expenditure shares (%)[b]		Chi-squared test statistics for expenditure shares H_0: Same distributions	Chi-squared test statistics for purchase frequencies H_0: Same distributions
	Nielsen Homescan™ Panel	Panel Used in this study	Nielsen Homescan™ Panel	Panel Used in this study		
Beef	70	70	36 (22)	36 (22)	0.570	
Pork	49	50	18 (16)	19 (16)	5.790 ***	
Chicken	64	63	34 (22)	32 (22)	6.870 ***	211 ***
Turkey	11	11	5 (10)	5 (10)	3.510 ***	
Seafood	16	15	7 (15)	8 (16)	2.570 **	

a: 14 households don't show their meat purchase information and therefore, are removed."*,**,***" represent 95%, 97.5% and 99% level of significance respectively.
b: The distributions of Canadian households profiles are computed based on data from Statistics Canada, 2006 Census.

Percentages of purchases for turkey, seafood and other types of meats are very small. A similar pattern is identified in the annual average meat expenditure (Figure 4.5). Beef and chicken expenditures are higher as compared to the others. Pork is ranked third in meat expenditure. Turkey and seafood expenditures are very small. A Chi-squared test suggests that the distributions of meat purchase frequencies in the whole panel and the study panel are different (Table 4.8). Further, the meat expenditure shares in the entire panel and the study panel are also statistically different with the exception of beef. This result suggests that beef expenditure shares in the sub-sample are representative of the entire panel but the other expenditure shares are not although the means are very close.

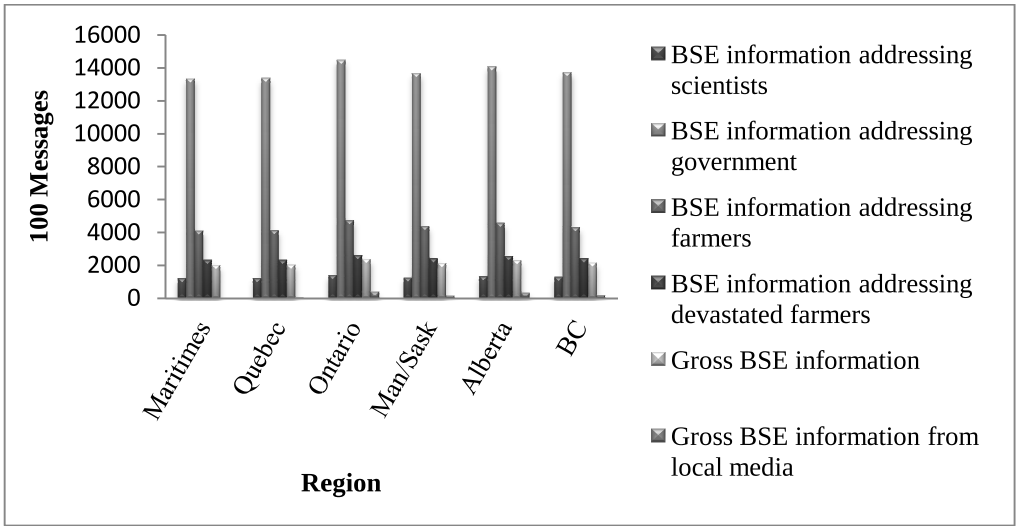
Figure 4.5 Average Annual Expenditure for Different Types of Meats Per Household



4.3.1.3 BSE Information Indices

The sources of media information about BSE and the methods of creating BSE information indices are the same as those used in the time series model. All BSE media indices are classified by region. A regional media index is defined as all the media information available for consumers in a certain region, including the information from media with national coverage and the information from media with coverage only in that region. On average, the BSE information addressing government is much more than BSE information addressing other subjects (Figure 4.6). The BSE information addressing other subjects except government is quite similar across regions.

Figure 4.6 Annual Average Media Information about BSE by Region, 2002-2007[a]



a: The subject indices about BSE such as BSE information addressing government, scientists and BSE affected producers may be larger than the gross BSE information because one article might have mentioned a subject like government many times.

4.3.1.4 Meat Retail Prices

In this analysis, the prices households face are regional retail meat prices. The available price data for beef, pork and chicken are national retail prices[37] and national and regional price indices for beef, pork and chicken (CANSIM II, 2006). The retail prices for different cuts of turkey for each province in Canada are available (AAFC, 2008). Regional turkey prices are computed as the weighted average prices of turkey above 5 kg (including 5 kg) and under 8 kg fresh because turkey prices in this category have fewer missing observations (5 missing records) than those in other categories (AAFC, 2008). The missing data for turkey prices in Western (Eastern) Canada provinces are replaced by the average prices of turkey above 5 kg (including 5 kg) and under 8 kg fresh in Western (Eastern) Canada. The price generation processes for the beef, pork, chicken and seafood prices are as follows:

Regional seafood prices are computed based on Nielsen Homescan™ panel data because almost all seafood products have UPC codes where the unit of consumption information is retrievable such as “kg” or “lbs”. If the unit coding of

37 The national retail prices of beef, pork is from CANSIM II Table 3260012. Beef retail prices include prices of different cuts of beef products such as round steak, sirloin steak, prime ribroas, blade roast, stewing beef and ground beef. The only pork price available is pork chop prices.

seafood is "unit", the seafood price is imputed as the average of seafood prices in different regions and different time periods in the sample data. Regional retail prices for beef, pork and chicken[38] are not available and cannot be computed from the Nielsen Homescan™ data because the reported beef, pork and chicken sales do not have explicit units of consumption information such as "kg" or "lbs". Given the price data available, the regional retail prices of beef, pork and chicken are approximated by:

$$P_i^{\,j} = P_i * \frac{PI_i^{\,j}}{PI_i} \tag{4.2}$$

where P_i^j is the regional retail price of meat i (i=beef, pork, chicken) in region j (j=Maritimes, Quebec, Ontario, Manitoba/Saskatchewan, Alberta and B.C.), PI_i^j is the price index of meat i in region j, PI_i is the national price index of meat I, P_i is the national retail price of meat I.

The national beef price P_{beef} is computed as a weighted average of prices of different beef cuts including round steak, sirloin steak, prime rib roast, blade roast, stewing beef and ground beef. The weights used are carcass portions of different cuts in carcasses of steers/heifers slaughtered (John, 2007). The national pork price is approximated by the national pork chop price, which is the only pork price available. The national (regional) consumer price indices for beef (pork, chicken) are represented by the national (regional) price indices for "Fresh or frozen beef (pork, chicken)" (CANSIM II, 2006).

In all regions, the mean nominal price of seafood is the highest, followed by pork and beef prices (Table 4.9). Chicken and turkey prices are lower than for other types of meats. In terms of price changes over time, the average beef prices in Alberta and Manitoba/Saskatchewan were declining from 2002 to 2003 but recovered afterwards. The beef prices in other regions were mainly increasing over time. Pork retail prices were the highest in either 2004 or 2005. Chicken and turkey retail prices reached their highest levels in 2007 in all provinces except

[38] The regional retail prices for different cuts of chicken products are also available from AAFC webpage Table 031: average monthly weighted retail poultry prices. However, they are not aggregated and may have biases during aggregation. To maintain consistency of data generation, we use the same approach as that of beef and pork to calculate regional prices of chicken.

Ontario where turkey prices reached their highest values in 2005. Seafood prices in the Maritime Provinces and Quebec were the highest in 2005 while in Manitoba/Saskatchewan, Alberta and B.C., seafood prices were the highest in 2004. In Ontario, seafood prices were the highest in 2002.

Table 4.9 Average Annual Retail Prices in Different Regions (Can. $ Per KG)

Region	Year	Beef	Pork	Chicken	Turkey	Seafood
Maritimes	2002	8.120	9.560	4.780	4.570	15.180
	2003	8.370	9.460	4.860	4.350	14.900
	2004	8.950	10.650	5.180	4.700	14.710
	2005	**9.330**[a]	**11.070**	5.340	5.050	**15.220**
	2006	9.290	9.440	5.330	4.730	14.310
	2007	8.990	9.270	**5.550**	**5.420**	14.100
Quebec	2002	8.120	9.560	4.780	4.900	16.970
	2003	8.380	9.740	4.920	5.010	16.570
	2004	8.960	10.510	5.400	5.210	17.340
	2005	9.080	**10.560**	5.270	5.260	**18.440**
	2006	8.980	9.650	5.360	5.280	17.570
	2007	**9.420**	9.950	**5.740**	**5.360**	17.210
Ontario	2002	8.120	9.560	4.780	4.380	**17.410**
	2003	8.250	9.360	5.100	4.660	17.250
	2004	8.500	**10.110**	5.400	4.660	16.570
	2005	8.540	10.030	5.440	**5.190**	16.100
	2006	8.520	9.640	5.510	5.050	16.070
	2007	**8.840**	9.410	**5.820**	4.240	16.430
Man./Sask.	2002	8.120	9.560	4.780	5.200	15.430
	2003	7.970	9.300	4.870	4.560	17.550
	2004	8.210	**9.850**	5.040	4.620	**18.500**
	2005	8.240	9.570	5.110	4.740	16.910
	2006	8.420	9.010	5.020	4.370	15.540
	2007	**8.560**	8.950	**5.510**	**4.990**	16.110
Alberta	2002	8.120	9.560	4.780	4.660	17.090
	2003	8.030	9.640	4.960	4.680	18.400
	2004	8.070	**9.770**	5.020	4.890	**19.260**
	2005	8.250	9.620	5.050	4.810	18.380
	2006	8.310	8.880	4.960	4.810	15.960
	2007	**8.510**	8.810	**5.330**	**5.020**	16.430
B.C.	2002	8.120	9.560	4.780	5.000	18.440
	2003	8.150	9.560	4.890	4.180	20.260
	2004	**8.610**	**9.980**	5.360	4.620	**20.710**
	2005	8.500	9.680	5.310	4.720	19.490
	2006	8.400	9.350	5.180	4.520	15.960
	2007	8.520	9.330	**5.470**	**5.000**	16.190

a: The highlighted numbers are of the highest value in their regions during 2002-2007.

4.3.1.5 Risk Perceptions and Attitudes about Eating Beef

Risk perception is defined as *a consumer's assessment of the uncertainty of risk* while risk attitude relates to *a consumer's general predisposition of risk* (Pennings et al., 2002; Schroeder et al., 2007). A high risk attitude score implies a high willingness to accept the risk or less aversion to risk and a high score for risk perception implies a high perceived risk (Pennings et al., 2002). It should be noted that the meaning of risk attitude score depends on the design of questions. For example, if the scale for a question "members of my household accept the risks of eating beef" is from one to five with one representing strongly disagree and five representing strongly agree, a high response score or risk attitude score implies a low risk aversion and a high willingness to accept the risk. In contrast, if the scale for the same question is from one to five with one representing strongly agree and five representing strongly disagree, a high response score or risk attitude score implies a high risk aversion and a low willingness to accept the risk.

The 2008 survey focused on recall of BSE, the perceived safety of eating beef, trust in different groups in society, and a number of other food safety related issues (Appendix F). The questionnaire and scales for variables (Table 4.10) were derived from an earlier study of Canadian consumer food safety attitudes and concerns (de Jonge et al., 2008). Three specific questions relate to risk perceptions including "when eating beef, my household is exposed to… (from very little risk to a great deal of risk)", "members of my household think eating beef is risky (from strongly disagree to strongly agree)" and "for members of my household, eating beef is …(not risky to risky)". Three specific questions are used to assess risk attitudes including "members of my household accept the risks of eating beef (strongly disagree to strongly agree)", "for members of my household, eating beef is worth the risk (strongly disagree to strongly agree)" and "my household is … the risk of eating beef (not willing to accept to willing to accept)". Answers to these questions are on a 1 to 5 Likert scale. The risk perception/attitude index is calculated as a simple average of the responses from the respective risk perception/attitude questions (Pennings et al., 2002; Schroeder et al., 2007).

Table 4.10 Descriptive Analysis of Risk Attitudes and Risk Perceptions

Studies / Mean and standard error / Questions	This study[a]					Schroeder et al. (2007)		
	Scale	Entire panel (4076 households in Canada)	Group 1	Group 2	Group 3	Questions	Scale	1002 households in Canada
Risk perception questions						Risk perception questions		
Question 2: when eating beef, my household is exposed to..(1=very little risk ,..,5= a great deal of risk)	5	1.990 (0.940)	1.360 (0.610)	2.800 (0.700)	1.550 (0.620)	when eating beef, I am exposed to… (1= No Risk at all, …, 10 = Very High Risk)	10	3.310 (2.140)
Question 4: members of my household think eating beef is risky (1=strongly disagree ,…,5= strongly agree)	5	1.980 (0.990)	1.320 (0.560)	2.810 (0.810)	1.570 (0.720)	Eating beef is risky (1=strongly disagree ,…,10= strongly agree)	10	3.340 (2.310)
Question 5: for members of my household, eating beef is …(1=not risky,…,5= risky)	5	2.040 (0.980)	1.320 (0.530)	2.950 (0.680)	1.590 (0.620)	I consider eating beef is … (1= Not at all Risky, …, 10 = Highly Risky)	10	3.380 (2.310)
Risk perception index	5	2.000 (0.850)	1.330 (0.430)	2.850 (0.500)	1.570 (0.460)	Risk perception index	10	3.300
T-test (same groupwise risk perception index)		Group 1 v.s. group 2: T-statistics: -218***; Group 2 v.s. group 3: T-statistics: 152***; Group 1 v.s. group 3: T-statistics: -13***						
Risk attitude questions						Risk attitude questions[b]		
Question 3: members of my household accept the risks of eating beef (1=strongly disagree ,…,5= strongly agree)	5	3.370 (1.150)	4.230 (0.930)	3.150 (0.750)	2.300 (1.000)	I rarely think about food safety when eating beef. (1= Strongly Agree, …, 10 = Strongly Disagree)	10	5.050 (3.080)
Question 6: for members of my household, eating beef is worth the risk (1=strongly disagree ,…,5= strongly agree)	5	3.400 (1.110)	4.340 (0.720)	3.030 (0.730)	2.460 (1.040)	For me, eating beef is worth the risk. (1= Strongly Agree, …, 10 = Strongly Disagree)	10	5.290 (2.920)
Question 7: my household is … the risk of eating beef (1=not willing to accept ,…,5= willing to accept)	5	3.610 (1.130)	4.570 (0.630)	3.060 (0.800)	2.980 (1.200)	My willingness to accept food safety risk when eating beef, I am (1= Very willing, …, 10 = Not at all willing)	10	4.470 (2.790)
Risk attitude index		3.460 (0.930)	4.380 (0.500)	3.080 (0.570)	2.580 (0.670)	Risk attitude index		4.900
T-test (same groupwise risk attitude index)		Group 1 v.s. group 2: T-statistics: 162***; Group 2 v.s. group 3: T-statistics: 47***; Group 1 v.s. group 3: T-statistics: 73***						

a:"*,**,***" represent 95%, 97.5% and 99% level of significance respectively. The standard errors are in parentheses.
b: The risk attitude questions used in this study following the same scale from strongly disagree to strongly agree (or from not willing to accept to willing to accept) as Pennings et al. (2002). Schroeder et al. (2007) applied a 1 to 10 scale in a reverse order from strongly agree to strongly disagree (or from willing to accept to not willing to accept) and therefore, the higher risk attitude index in Schroeder et al. (2007), the higher risk averse and the less willing to accept the risk.

The descriptive analyses of each question and of the risk perception/attitude indices are shown in Table 4.10. Based on the descriptive analysis for the entire study panel, the risk perception index is 2, which suggests a fairly low risk perception and the risk attitude index is 3.46, a small aversion to risk associated with beef. The risk perception/attitude indices in this study can be compared to those generated by Schroeder et al. (2007). As shown in Table 4.10, the risk attitude questions from Schroeder et al. (2007) have a 1 to 10 scale from strongly agree to strongly disagree (or from willing to accept to not willing to accept), which is a reverse to the scale from strongly disagree to strongly agree (or from not willing to accept to willing to accept) in this study. The risk attitude index is 4.9 from Schroeder et al. (2007), which is lower than a neutral attitude (5) on a 1 to 10 scale and suggests that consumers are willing to accept the risks of eating beef. Such a result is similar to the result in this study. The risk perception questions from Schroeder et al. (2007) on a 1 to 10 scale from not risky (strongly disagree) to very risky (strongly agree) generate a risk perception index of 3.3, implying low risk perceptions which are similar to this study.

In addition to the risk attitude and perception questions, the respondents answered a question about whether or not they ate beef – if they didn't they did not complete the risk attitude/perception questions. It is worth noting that although 238 respondents responded that they did not eat beef, the panel purchase data showed that those households did purchase beef during the period of the analysis. Clearly beef purchases must have been for other members of the household. These 238 households were treated as a separate group for further analysis. 3838 households in the survey reported beef-eating.

The beef attitude/perception questions make it possible to classify households into different groups by their attitudes/perceptions and analyze each group separately. K-mean cluster analysis[39] is applied to classify households. The initial centre of each cluster, the iteration history and the final cluster centre are also reported (Table 4.11). Households are clustered into three groups with 1437

[39] Principal component analysis is also applied and the result of cluster membership is similar to that of cluster analysis.

households in group 1, 1552 in group 2 and 849 in group 3 (Table 4.12). A fourth group with the 238 households where the respondents reported no beef-eating and therefore, didn't answer risk perception/attitude questions is also analyzed. The frequency analysis (Table 4.12) and the final cluster centre for each group (Table 4.11) show that a major number of the respondents in group 2 chose relatively neutral responses such as either agree or disagree, either risky or not risky in the individual risk attitude/perception questions. Their mean risk attitude score and risk perception score were 3.08 and 2.85 respectively (Table 4.10).

Most respondents in group 1 feel little risk in eating beef (mean score of risk perceptions 1.33) and are less averse to the risks related to beef (mean score of risk attitudes 4.38). Most respondents in group 3 also have low risk perceptions (mean score of risk perceptions 1.57) but are more averse to or neutral in the risk of eating beef (mean score of risk attitudes 2.58) (Table 4.10). For example, 54.6% of the households in group 3 disagree that they would accept the risks of eating beef as compared to 5.1% of the households in group 1 and 13.6% of the households in group 2 with the responses to the same question. 45.4% of the households in group 3 disagree that for members of their households, eating beef is worth the risk as compared to 1.4% of the households in group 1 and 15.9% of the households in group 2 with responses to the same questions (Table 4.12). As compared with other groups, group 1 has lower risk perceptions and low aversion to risks associated with beef, and therefore, can be described as a "confident group". Group 2 has medium risk perceptions and risk attitudes, and therefore, can be described as a "neutral group". Group 3 has lower risk perceptions and high aversions to risks associated with beef, and therefore, can be described as a "somewhat concerned" group. The groupwise risk perception/ attitude indices are compared statistically and the results suggest significant differences among various groups (Table 4.10). Because the responses to risk perception/attitude questions are ordinal and not normally distributed, non-parametric tests without assumptions of normality are also applied to examine differences across groups including median tests, Kruskal Wallis Tests and a Jonckheere-Terpstra Test (Table 4.12) (Siegel and Castellan, 1988). These tests all suggest differences in the distribution of responses for the risk perception/attitude questions across the three groups.

Table 4.11 The K-Mean Cluster Procedure and Results

Initial Cluster Centers			
Questions	Cluster		
	1	2	3
Question 2: when eating beef, my household is exposed to… (very little risk to a great deal of risk)	1	5	1
Question 3: members of my household accept the risks of eating beef (strongly disagree to strongly agree)	5	5	1
Question 4: members of my household think eating beef is risky (strongly disagree to strongly agree)	1	5	4
Question 5: for members of my household, eating beef is … (not risky to risky)	1	5	1
Question 6: for members of my household, eating beef is worth the risk (strongly disagree to strongly agree)	5	2	1
Question 7: my household is … the risk of eating beef (not willing to accept to willing to accept)	5	3	1
Iteration History[a]			
Iteration	Change in Cluster Centers		
	1	2	3
1	2.181	3.651	3.188
2	.498	.358	.438
3	.270	.219	.386
4	.110	.082	.181
5	.046	.018	.096
6	.053	.014	.107
7	.021	.023	.055
8	.000	.009	.016
9	.000	.004	.006
10	.000	.011	.020
11	.000	.003	.006
12	.000	.000	.000
Final Cluster Centers			
Questions	Cluster		
	1	2	3
Question 2: when eating beef, my household is exposed to… (very little risk to a great deal of risk)	1	3	2
Question 3: members of my household accept the risks of eating beef (strongly disagree to strongly agree)	4	3	2
Question 4: members of my household think eating beef is risky (strongly disagree to strongly agree)	1	3	2

Question 5: for members of my household, eating beef is … (not risky to risky)	1	3	2
Question 6: for members of my household, eating beef is worth the risk (strongly disagree to strongly agree)	4	3	2
Question 7: my household is … the risk of eating beef (not willing to accept to willing to accept)	5	3	3
Distances between Final Cluster Centers			
Cluster	1	2	3
1		3.484	3.151
2	3.484		2.450
3	3.151	2.450	
Number of Cases in each Cluster			
Cluster	1	1437	
	2	1552	
	3	849	
Valid		3838	
Missing[b]		238	

a: Convergence achieved due to no or small change in cluster centers. The maximum absolute coordinate change for any center is .000. The current iteration is 12. The minimum distance between initial centers is 7.348.
b: The missing data are households who reporting no beef-eating.

Table 4.12 Response Frequencies for Questions of Attitude Towards Eating Beef

Questions of eating beef	Resp.	Group 1		Group 2		Group 3		Test statistics H_0: Same distributions from three groups		
		Freq.	%	Freq.	%	Freq.	%	K.W. Test[b]	Med test	J-T Test
Q2: When eating beef, my household is exposed to … 1: Very little risk 5: A great deal of risk	1	**1015[a]**	**70.600**	62	4.000	**436**	**51.400**			
	2	**338**	**23.500**	**365**	**23.500**	**357**	**42.000**			
	3	77	5.400	**963**	**62.000**	54	6.400			
	4	6	.400	143	9.200	2	.200			
	5	1	.100	19	1.200	0	0.000			
	Total	1437	100. 000	1552	100.000	849	100.000	2036 ***	184 ***	291 ***
Q3: Members of my household accept the risks of eating beef 1: Strongly disagree 5: Strongly agree	1	49	3.400	39	2.500	**224**	**26.400**			
	2	24	1.700	172	11.100	**239**	**28.200**			
	3	130	9.000	**906**	**58.400**	**303**	**35.700**			
	4	**585**	**40.700**	**389**	**25.100**	70	8.200			
	5	**649**	**45.200**	46	3.000	13	1.500			
	Total	1437	100. 00	1552	100.000	849	100.000	1707 ***	157 ***	838 ***
Q4: Members of my household think eating beef is risky 1: Strongly disagree 5: Strongly agree	1	**1024**	**71.300**	35	2.300	**448**	**52.800**			
	2	**381**	**26.500**	**517**	**33.300**	**348**	**41.000**			
	3	21	1.500	**768**	**49.500**	35	4.100			
	4	7	.500	171	11.000	9	1.100			
	5	4	.300	61	3.900	9	1.100			
	Total	1437	100. 000	1552	100. 000	849	100.000	2084 ***	168 ***	296 ***
Q5: For members of my household,	1	**1019**	**70.900**	7	.500	**408**	**48.100**			
	2	**387**	**26.900**	**330**	**21.300**	**383**	**45.100**			
	3	24	1.700	**991**	**63.900**	57	6.700	2423 ***	228 ***	300 ***

eating beef is … 1: Not risky 5: Risky	4	6	.400	**180**	**11.600**	1	.100			
	5	1	.100	44	2.800	0	0.000			
	Total	1437	100. 000	1,552	100. 000	849	100. 000			
Q6: For members of my household, eating beef is worth the risk 1: Strongly disagree 5: Strongly agree	1	10	.700	59	3.800	**205**	**24.100**			
	2	10	.700	188	12.100	**181**	**21.300**			
	3	123	8.600	**969**	**62.400**	**343**	**40.400**			
	4	**631**	**43.900**	**315**	**20.300**	106	12.500			
	5	**663**	**46.100**	21	1.400	14	1.600			
	Total	1437	100. 000	1552	100. 000	849	100. 000	1962 ***	184 ***	797 ***
Q7: My household is … the risk of eating beef 1: Not willing to accept 5: Willing to accept	1	7	.500	73	4.700	139	16.400			
	2	8	.600	196	12.600	115	13.500			
	3	44	3.100	**896**	**57.700**	**306**	**36.000**			
	4	**474**	**33.000**	**345**	**22.200**	**199**	**23.400**			
	5	**904**	**62.900**	42	2.700	90	10.600			
	Total	1437	100. 000	1552	100. 000	849	100. 000	1877 ***	152 ***	987 ***

a:"*,**,***" represent 95%, 97.5% and 99% level of significance respectively. The highlighted categories are with high frequencies of responses in each question and each group.

b: K.W. test : Kruskal Wallis Test ; J-T test: Jonckheere-Terpstra Test; Med. Test: median test.

The four groups have similarities and differences in their demographic profiles (Table 4.13). In terms of similarities, English is a dominant language in all groups. Also, most of the households have no children under 18 and many household heads are beyond 65 years of age. Most of the households have origin as urban. In each group, a large number of households are from Ontario or Quebec. In terms of differences, there are many two-member households in group 1 ("confident group"), group 2 ("neutral group") and group 3 ("somewhat concerned group") while many single member households are present in group 4 ("report no beef-eating group"). Further, there are many households in group 4 with low incomes (< $20,000) while in group 1, 2 and 3, high-income ($70,000+) households account for large percentages. In terms of education levels of household heads, there are many household heads with higher education in group 1 and group 4 while there are many household heads with lower education in group 2 and group 3. Therefore, it seems that households who are more risk averse in beef consumption (group 3) have lower education levels than households in other groups. A Chi-squared test suggests significant differences across groups in sample region, household size, age of children, income, education level of household head and origin. There are also significant differences in language used among group 1, 2 and 3 but group 4 has no significant differences with group 2 or group 3. There are significant difference in age of household head between group 1 and group 2 and between group 2 and group 3 but no significant differences in age of household head among group 1, group 3 and group 4.

Table 4.13 Demographic Profiles for Different Groups, 2006

Demog. variable	Categories	Group				Pearson Chi-squared test statistics H0: Same distributions from groups					
		(1)	(2)	(3)	(4)	(1) v.s. (2)	(1) v.s. (3)	(1) v.s. (4)	(2) v.s. (3)	(2) v.s. (4)	(3) v.s. (4)
Region	Maritimes	162	233	121	21	490 ***	252 ***	75 ***	521 ***	134 ***	134 ***
	Quebec	255	**441**	218	**68**						
	Ontario	**399**[a]	377	**227**	60						
	Manitoba / Saskatchewan	178	146	86	23						
	Alberta	234	165	106	23						
	BC	209	190	91	43						
Language	English	**1244**	**1157**	**664**	**180**	193 ***	51 ***	25 ***	6 **	0.14	0.93
	French	193	395	185	58						
Household size	Single Member	393	442	182	**116**	617 ***	319 ***	802 ***	429 ***	912 ***	831 ***
	Two Members	**634**	**674**	**367**	79						
	Three Members	179	232	153	18						
	Four Members	165	150	117	18						
	Five - Nine Plus Members	66	54	30	7						
Age of child	Under 6 only	2	1	20	2	132 ***	937 ***	262 ***	154 ***	371 ***	475 ***
	Age 6 to 12 only	32	27	36	2						
	Age 13 to 17 only	58	53	68	11						
	Under 6 and age 6 to 12	103	88	31	7						
	Under 6 and age 13 to 17	47	59	30	2						
	Age 6 to 12 and age 13 to 17	41	46	47	7						
	Under 6, age 6 to 12 and age 13 to 17	67	60	9	1						
	No children under 18	**1087**	**1218**	**608**	**206**						
Age of household head	18-34	34	16	12	4	38 ***	8	3.2	27 ***	2	6.3
	35-44	229	212	159	30						
	45-54	392	378	223	63						
	55-64	361	407	207	64						
	65+	**421**	**539**	**248**	**77**						
Income	< $20,000	103	154	87	**50**	129 ***	36 ***	90 ***	11 *	35 ***	36 ***
	$20,000-$29,999	168	246	117	40						
	$30,000-$39,999	195	271	135	37						
	$40,000-$49,999	187	244	128	32						
	$50,000-$69,999	292	286	152	33						

	$70,000+	**492**	**351**	**230**	46						
Education level of household head	NOT high school educated	175	236	156	21	217 ***	154 ***	23 ***	55 ***	39 ***	41 ***
	High school educated	257	293	173	44						
	Some college or tech	180	265	130	32						
	College or tech graduates	303	**356**	**191**	49						
	Some university	151	131	68	28						
	University graduates	**371**	271	131	**64**						
Origin	National urban	**873**	**927**	**485**	**166**	273 ***	113 ***	92 ***	100 ***	85 ***	70 ***
	National rural	564	625	364	72						

a:"*","**","***", represents 95%, 97.5% and 99% significant levels.

In terms of meat expenditure shares in each group, the average expenditure shares of beef in group 1 ("confident group") and group 2 ("neutral group") are higher than in other groups (Table 4.14). Group 4 ("reporting no beef eating group") has the lowest average expenditure share for beef and the highest average expenditure share for chicken (seafood) among the four groups, suggesting that consumers in group 4 substitute more chicken or seafood for beef than consumers in other groups. The hypothesis of the same means across groups is rejected for most of the meats with the exception of beef, pork, turkey expenditure shares in group 1 and group 2, and chicken, turkey and seafood expenditure shares in group 2 and group 3 (Table 4.14).

Historically, Canadian expenditure shares for different meats have presented various trends (Figure 4.7-4.11). During the period 2002-2007, the annual average beef expenditure shares in group 4 were declining while those in other groups showed declines up to 2005 and recovery afterwards. The annual average pork expenditure shares in group 3 and group 4 increased from 2002 to 2007 while those in other groups were relatively stable. Group 1 showed a continuous increase in annual average chicken expenditure share from 2002 to 2007 while group 3 and group 4 showed increases in 2003 and 2006 or 2007. All groups have had declines in turkey expenditure share but an increase in seafood expenditure share over time. In all the graphs, group 3 and group 4 have larger fluctuations in meat expenditure share than other groups. After the BSE outbreak in Canada in 2003, the average annual beef expenditure shares of all groups declined temporarily and group 3 and group 4 had larger declines as compared to the other groups. At the same time, the average annual chicken expenditure shares increased temporarily, suggesting some substitution of chicken for beef. The average annual pork and seafood expenditure shares also increased in 2004 or 2005 in all groups, implying substitution of these other meats for beef.

Table 4.14 Average Annual Expenditure Shares (%) for Different Types of Meats, 2002-2007

Meat type	Group				T-test H0: Same means from groups[a]					
	(1)	(2)	(3)	(4)	(1) v.s. (2)	(1) v.s. (3)	(1) v.s. (4)	(2) v.s. (3)	(2) v.s. (4)	(3) v.s. (4)
Beef	36.170	36.380	35.600	22.070	0.330	2.240 **	21.030 ***	2.590 ***	21.350 ***	19.260 ***
Pork	19.100	18.700	19.950	15.450	1.820	3.370 ***	8.410 ***	5.100 ***	7.680 ***	9.900 ***
Chicken	30.710	31.700	31.760	37.240	2.960 ***	2.300 **	11.150 ***	0.190	10.050 ***	9.840 ***
Turkey	5.140	5.020	5.020	7.900	0.690	0.330	6.070 ***	0.240	6.310 ***	6.080 ***
Seafood	8.870	8.200	7.670	17.340	2.420 **	3.570 ***	10.090 ***	1.540	11.080 ***	11.430 ***

a: ”*,**,***” represent 95%, 97.5% and 99% level of significance respectively.

Figure 4.7 Annual Average Beef Expenditure Shares by Group, 2002-2008

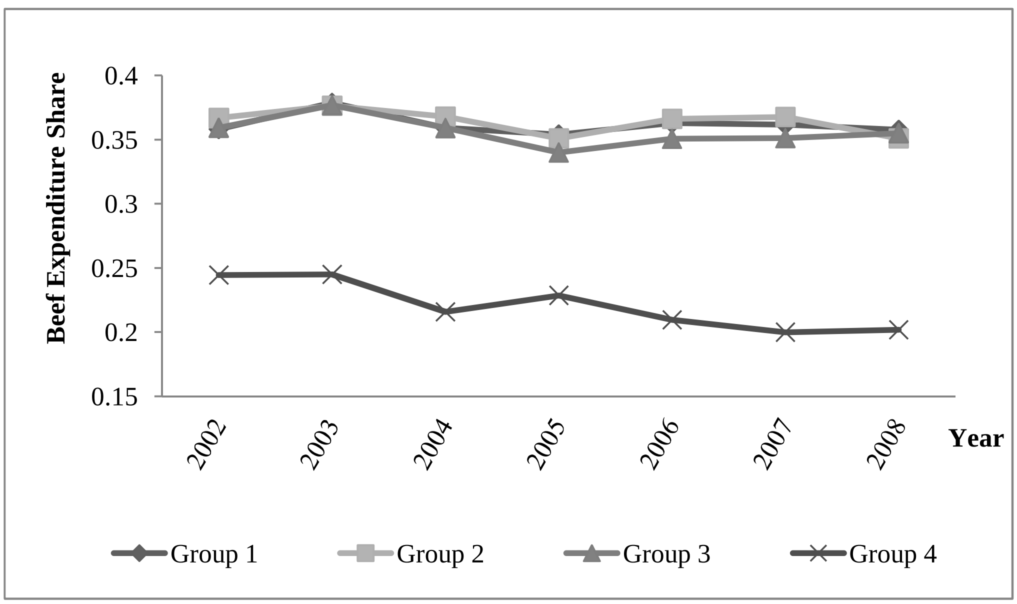


Figure 4.8 Annual Average Pork Expenditure Shares by Group, 2002-2008

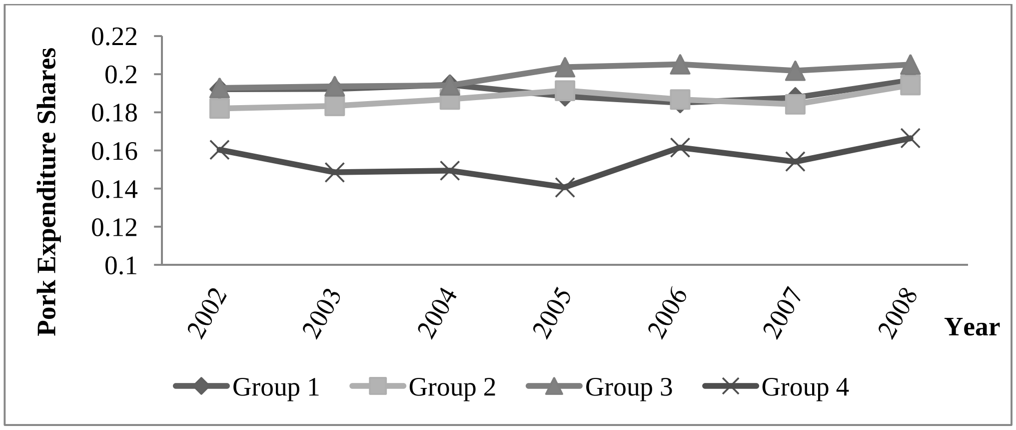


Figure 4.9 Annual Average Chicken Expenditure Shares by Group, 2002-2008

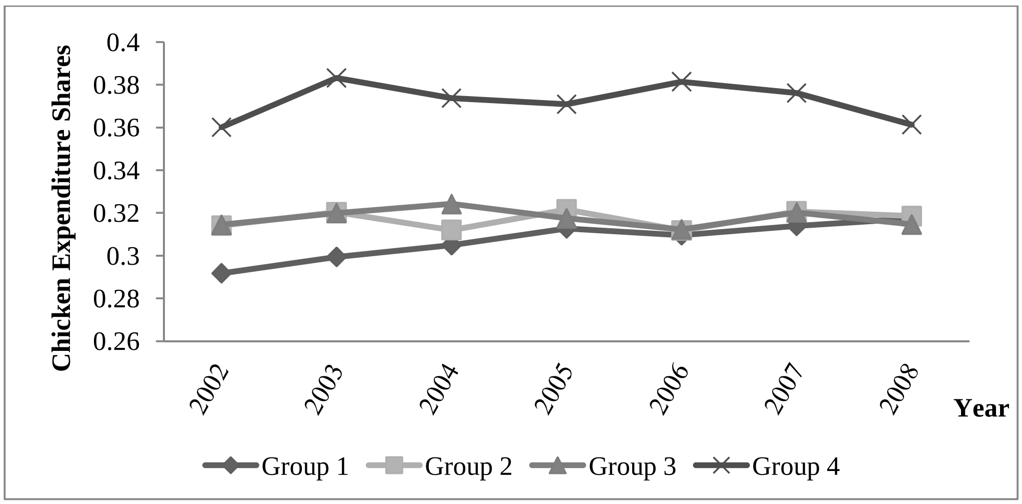


Figure 4.10 Annual Average Turkey Expenditure Shares by Group, 2002-2008

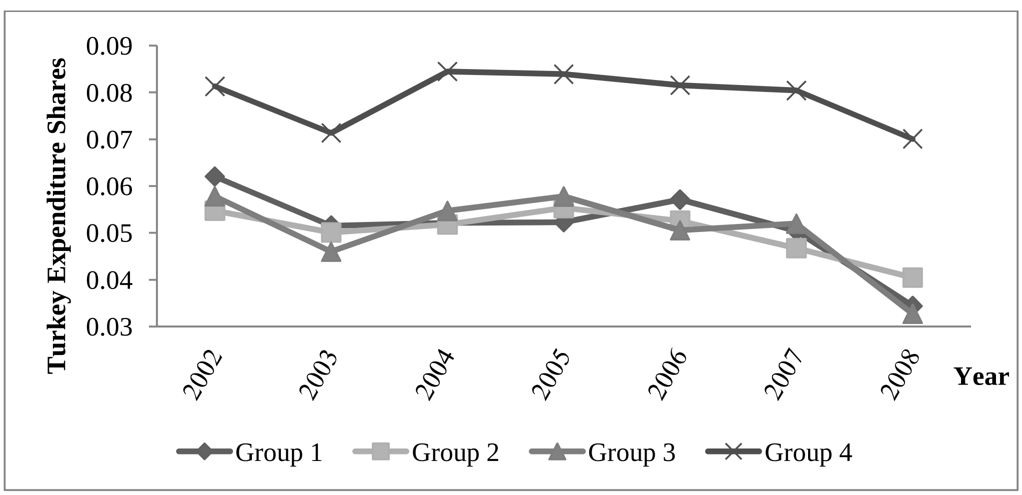
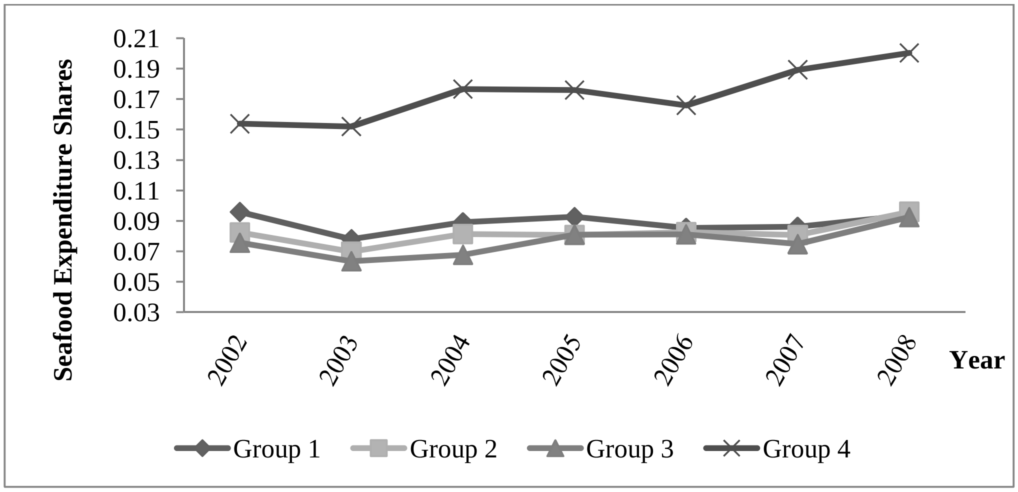


Figure 4.11 Annual Average Seafood Expenditure Shares by Group, 2002-2008



The differences in these household groups can also be shown by their various responses to other survey questions about perceived confidence in beef safety, livestock production related concerns and recall of news messages about BSE (Table 4.15). For example, 83% of the households in group 1 are confident about beef safety while only 26% of group 2, 64% of group 3 and 22% of group 4 have the same confidence levels. 57% of the households in group 3 are concerned about animal diseases as compared to 42% of the households in group 1 and 74% of the households in group 2 or group 4 with the same concern levels. The four groups recalled almost the same media coverage about BSE (mad cow disease). However, only 6% of the households in group 1 believe that if a Canadian cow is found with BSE (mad cow disease) the risk to their families is high as compared to 13% in group 2, 10% in group 3 and 18% in group 4 with the same belief. Further, only 3% of the households in group 1 reported a large impact on their confidence in beef safety if they had any awareness of a BSE (mad cow disease) incident in Canada over the past five years, as compared to 23% in group 2, 10% in group 3 and 34% in group 4 with the same responses. The non-parametric tests without assumption of normality (K.W. test and Median test) also suggest differences in the distributions of responses for questions about perceived confidence in beef safety, animal production related concerns and recall of news messages about BSE among the four groups.

Table 4.15 Response Frequencies in Questions about Perceived Safety of Beef, Animal Production Related Concerns and Recall of News Messages about BSE

Questions	Resp.	Group 1		Group 2		Group 3		Group 4		Test statistics: H0: Same distributions	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	K.W. Test[b]	Med. test
Please indicate how much confidence you, generally, have in the safety of beef. 1=No confidence at all 5=Complete confidence	1	3	0.01	46	3	6	1	47	20	1218 ***	464 ***
	2	19	0.99	195	13	38	4	40	17		
	3	232	16	902	58	260	31	99	42		
	4	802	56	394	25	436	51	42	18		
	5	381	27	15	1	109	13	10	4		
To what extent are you concerned about animal diseases? 1=Not at all concerned 5=Very concerned	1	68	5	6	0.01	19	2	2	1	384 ***	160 ***
	2	249	17	50	2.99	86	10	9	4		
	3	518	36	350	23	260	31	51	21		
	4	347	24	570	37	249	29	78	33		
	5	255	18	576	37	235	28	98	41		
To what extent are you concerned about BSE (mad cow disease) and Creutzfeldt Jakob Disease (vCJD)? 1=Not at all concerned 5=Very concerned	1	126	9	13	1	41	5	6	3	420 ***	201 ***
	2	321	22	72	5	95	11	14	6		
	3	411	29	338	22	238	28	48	20		
	4	276	19	451	29	211	25	54	23		
	5	303	21	678	44	264	31	116	49		
To what extent have you seen, heard, or read any news messages in the media about BSE (mad cow disease) over the past five years? 1=Very few messages 5=Many messages	1	41	3	44	3	22	3	8	3	1.2	1.4
	2	134	9	137	9	67	8	16	7		
	3	638	44	675	43	385	45	91	38		
	4	352	24	383	25	199	23	58	24		
	5	214	15	217	14	122	14	36	15		
	missing[a]	58	4	96	6	54	6	29	12		
If a Canadian cow is found with BSE (mad cow disease) the risk to my family is: 1=Very low 5=Very high	1	459	32	83	5	151	18	69	29	562 ***	437 ***
	2	538	37	401	26	279	33	50	21		
	3	286	20	551	36	243	29	45	19		
	4	69	5	306	20	92	11	31	13		
	5	27	2	115	7	30	4	14	6		
	missing	58	4	96	6	54	6	29	12		
If you have any awareness of a BSE (mad cow disease) incident in Canada over the past five years, has this had any impact on your confidence in the safety of beef products? 1=A very small impact 5=A very large impact 6=Don't know	1	937	65	261	17	346	41	55	23	796 ***	611 ***
	2	211	15	315	20	165	19	27	11		
	3	150	10	475	31	178	21	37	16		
	4	29	2	202	13	49	6	18	8		
	5	14	1	159	10	32	4	61	26		
	6	38	3	44	3	25	3	11	5		
	missing	58	4	96	6	54	6	29	12		

a: The system missing observations are from households who responded they never seen, heard, or read about BSE (mad cow disease)
b: "*,**,***" represent 95%, 97.5% and 99% level of significance respectively. J-T test or Jonckheere-Terpstra Test is not available.

4.3.2 Revealed Preference and Non-Parametric Structural Break Test

The household panel data are aggregated to quarterly and annual levels to decrease the zero or missing observations from weekly or monthly data (Appendix B). The structural break points selected for quarterly data include the second quarter of 2003 (the first North American BSE-infected cow was found in Canada), the first quarter of 2004 (one BSE-infected cow was found in the U.S.), the first quarter of 2005 (two BSE-infected cows were found in Canada) and the third quarter of 2006 (three BSE-infected cows were found in Canada)[40]. The structural break points selected for annual data include 2003, 2004, 2005 and 2006 because they are the years after the first domestic BSE-infected cow was found in Canada and they correspond to the discovery of other BSE-infected cows in Canada. In the same way as the non-parametric structural break test in the time series section, the R matrix (Chapter 3 section 3.4) is constructed and split into three sections for before, after and spanning sections around possible structural break points. A table S (Chapter 3 section 3.4) is also constructed with n individuals or households as rows and violation numbers of before, after and spanning parts of possible structural break point as columns.

The non-parametric structural break test is implemented on the annual and quarterly household panel data, annual and quarterly sub-sample of the household panel data and annual and quarterly household panel data of the different groups. The numbers of violations of the Weak Axiom of Revealed Preference (WARP) in table S are shown in Figures 4.12 and 4.13[41].

[40] The possible structural breaks in the fourth quarter, 1993 and the first quarter, 1996 cannot be tested by household panel data because the household panel data we have only cover the period from 2002 to 2008. However, we can test the third quarter of 2006 when three BSE-infected cows were found in Canada.

[41] The mean ranks and Friedman and Kendall tests are reported in Table C.3 and C.4 in Appendix C due to their lengthy tables.

Figure 4.12 Number of Violations of WARP based on Annual Data

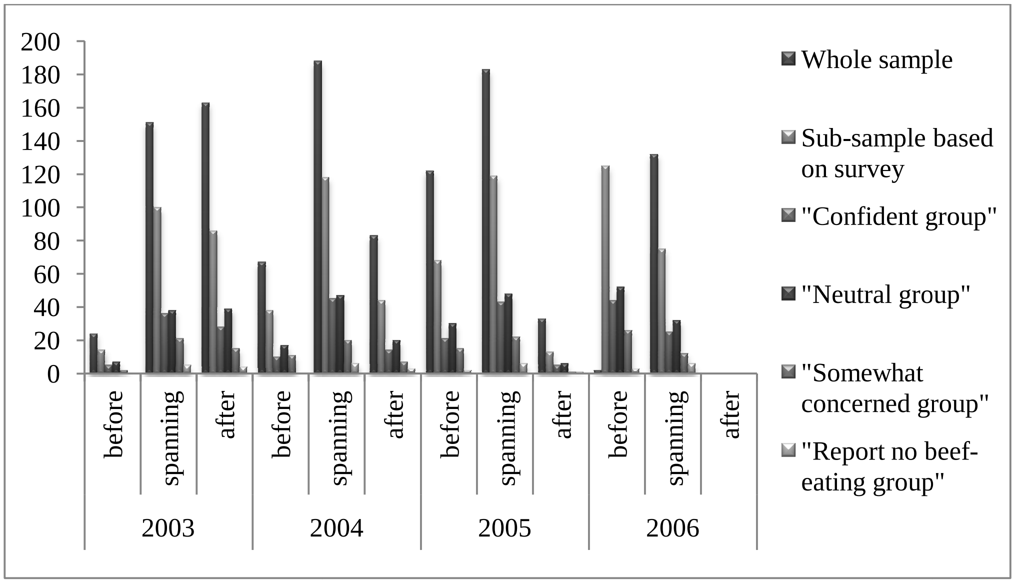
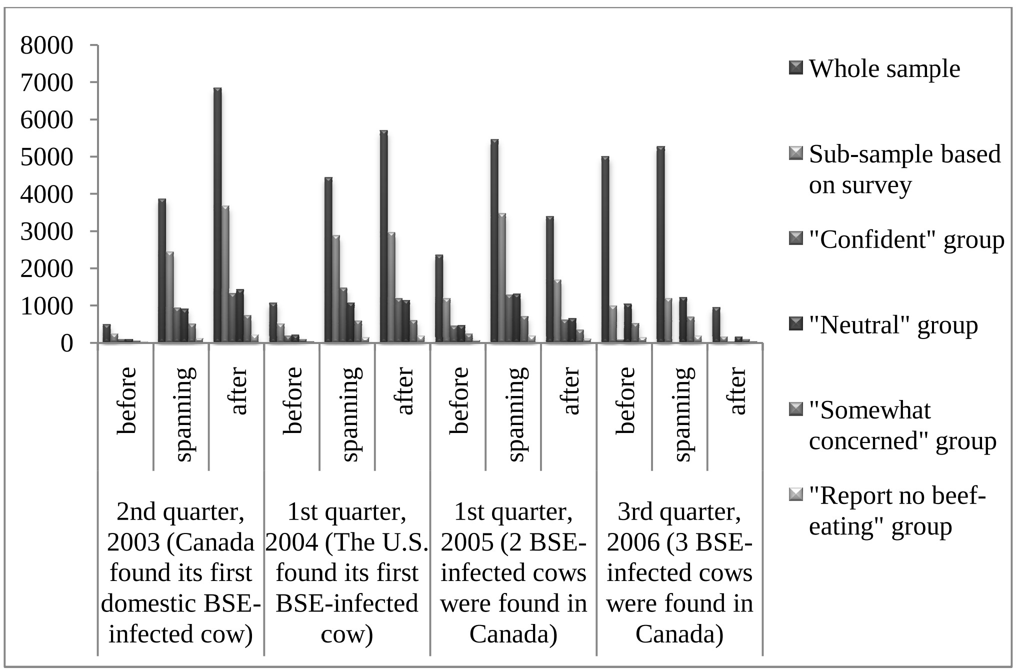


Figure 4.13 Number of Violations of WARP based on Quarterly Data



It is shown from the graphs above that the quarterly numbers of violations of WARP in the before, spanning and after sections of table S (Chapter 3 section 3.4) are quite different from each other, implying certain structural changes or taste shifts at the second quarter of 2003, the first quarter of 2004, the first quarter of 2005 and the third quarter of 2006. The annual numbers of violations of WARP in different sections of table S also indicate structural changes in 2003, 2004, 2005 and 2006. Further, the second quarter of 2003, the first quarter of 2004 and the third quarter of 2006 show larger changes in the numbers of violations of WARP and therefore, imply larger structural changes as compared with the first quarter of 2005.

The results from evaluating the violation numbers of WARP in different sections of S are consistent with the results from non-parametric statistical tests including Friedman and Kendall tests (Table C.3 and C.4). For the whole household panel, the sub-sample of household panel (study panel) and the household panel from each group, Friedman and Kendall tests suggested structural breaks in the second quarter of 2003, the first quarter of 2004, the first quarter of 2005 and the third quarter of 2006 based on the quarterly data and structural breaks in 2003, 2004, 2005 and 2006 based on the annual data. However, by comparing the differences in the distributions before and after these time periods as represented by the mean ranks of violation numbers of WARP, the second quarter of 2003, the first quarter of 2004 and the third quarter of 2006 present higher magnitude of structural changes than the first quarter of 2005.

4.3.3 Demand Model with Predictive Difference Approach

4.3.3.1 Parametric Structural Break Test and Poolability Test

The parametric structural break tests based on likelihood ratios are employed to provide robust evidence about structural changes given sufficient observations before and after possible structural break points. The likelihood ratios come from the two-stage demand system estimated in the next section. The structural break points selected for annual data include 2004 and 2006 because they are the years after the first domestic BSE-infected cow was found in Canada and they correspond to the discovery of other BSE-infected cows in Canada. The structural break test in 2003 and 2005 cannot be employed because the demand model based on the data in 2002 or data in 2004 failed to converge[42]. The parametric structural break tests are only employed for the demand models based on annual panel data from different groups. The test statistics are reported in Table 4.16.

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[42] The structural break test suggests that there are preference changes in 2004 and therefore, to test a structural change in 2005, we need to estimate the demand model based on the data of 2004 and the data after 2004. However, the model based on the data of 2004 failed to converge.

Table 4.16 Results of Parametric Structural Break Test for Annual Group Panel Data

Group		Log-likelihood					Likelihood ratio		P-value	
		A: 2002 - 2003	B: 2004 - 2005	C: 2006 - 2007	D: 2004 - 2007	E: 2002 - 2007	A v.s. D	B v.s. C	A v.s. D	B v.s. C
Group1		1329	2767	2785	5382	6160	110	341	0	0
Group2		1904	3438	3814	7061	8559	811	382	0	0
Group3		1320	1969	2141	3915	4895	681	389	0	0
Group4[a]		N/A	-144	-73	-335	-474	N/A	237	N/A	0
Poolability test	Likelihood ratio	3784	1556	1758	1688	4628				
	P-value	0	0	0	0	0				

a: Demand model based on the data of group 4 from 2002 to 2003 failed to converge.

The results show that all consumer groups have structural breaks in their meat consumption at 2004, 2006, which may be the result of BSE outbreaks. The data poolability test rejects the pooling of data and therefore, suggested separate analysis for the individual consumer groups.

In summary, both the parametric and non-parametric structural break tests suggest possible shifts in consumer tastes due to the outbreak of BSE. The changes in consumer tastes in different meats may be represented by the changes in meat demand elasticities and the changes in elasticities of substitution, which will be illustrated in the following model estimation section.

4.3.3.2 Model Estimation

The panel data used for the demand model estimation are annual household panel data of different groups. These groups come from the cluster analysis of sub-sample of household panel data (study panel). The use of the annual sub-sample panel data can have both pros and cons. First, relatively less households are included in the sub-sample data as compared with the whole sample data and there are fewer missing records in sub-sample observations, which can reduce the estimation burden and errors. Further, the descriptive analyses of household panel data in the previous sections show that the sub-sample data have quite similar frequencies in demographic profiles as the whole sample data though statistically different. Second, the sub-sample data are aggregated to an annual level, which decreases the number of missing records significantly. However, this aggregation is based on the assumption that whenever the consumption of certain meat from one household is missing, it is zero. Given the comprehensiveness of ACNielsen Homescan™ panel data, the zero consumption in missing records may not be a bad assumption. The data generation procedure and the methods dealing with missing and observations with incorrect coding are discussed in Appendix B.

Similar to the time series data model, the economic properties implied by a well-defined utility function (e.g. symmetry, zero homogeneity) are imposed on the panel data demand system due to the high multicollinearity (condition number=171>30) and failure of convergence of the demand system without these properties. The failure of convergence of the demand system without these properties might suggest that Canadian consumers follow a well-defined utility function in their decision-making. The adding-up property in the panel data demand system is maintained by imposing the constraints that parameters of every demographic variable in all share equations are summed to zero. Homothetic separability is also imposed based on the requirement of two-stage demand system (Green, 1976). The estimation results based on the period before BSE outbreak (2002-2003) and the post-BSE period (2004-2007) are reported in Tables C.5 to C.8 in Appendix C.

From the results of the model estimation, several conclusions can be reached. First, the demographic variables have significant impacts on meat demand in all groups[43]. As suggested by the parameter estimates, region, household size, age and presence of children, education level of household heads, annual income and origin all have an impact on the total meat expenditure in different groups. Specifically, based on the estimation of the total meat expenditure equation (the first stage of the demand system), the households in group 1("confident group"), group 2 ("neutral group") or group 3 ("somewhat concerned group") and from Maritime Provinces or Quebec have significantly more meat expenditure per

[43] Due to the fact that the models based on period 2002-2003,2004-2005 and 2006-2007 have high multi-collinearity among estimated parameters, the parameter significance may not be reliable. Therefore, we use the models based on 2002-2007 and 2004-2007 to evaluate the significance of parameters.

household than the households in the same groups in other provinces. Single-member households in group 2 or group 3 have significantly lower meat expenditure than other types of households in group 2 or group 3. In group 3, household heads with ages between 18 and 34 have significantly lower meat expenditure than household heads in other age categories. In group 1, households with annual income lower than $30,000 have significantly lower meat expenditure than households with annual income more than $30,000. In group 1, households with origin as “rural” have lower meat expenditure than households with origin as “urban”, which might indicate that households who initially lived in rural areas eat less meat than those who initially lived in urban areas. Such a result might be due to the fact that less income is available for the households from rural areas as compared to those from urban areas.

As far as the individual meat expenditure share (the second stage of the meat demand system) concerned, the households in group 2 or group 3 and from Ontario have significantly lower beef expenditure shares than households in group 2 or group 3 but from other regions. In group 1, households with four members have significantly lower beef expenditure shares than other households. In group 3, households with a single member have significant lower beef shares than other households. In group 1 and group 2, households that have children 13 to 17 years old only have significant higher beef expenditure shares than other households. Within group 3, households that have children with ages 6 to 12 and ages 13 to 17 have significant lower beef expenditure shares than other households. In group 1, households with education levels as “College or Tech. Graduates” have significantly higher beef expenditure shares than other households.

In terms of pork expenditure share, households in group 1 or group 2 and from Maritime Provinces have significantly lower pork expenditure shares than the households in group 1 or group 2 but from other provinces. While households in group 3 and from Maritime Provinces have significantly higher pork expenditure shares than the households in group 3 but from other provinces. Households in group 1 and from Alberta have significantly higher pork expenditure shares than the households in group 1 but from other provinces. Households in group 2 and from Manitoba, Saskatchewan have significantly higher pork expenditure shares than households in group 2 but from other provinces. Households in group 3 and with two or three members have significant lower pork expenditure shares than households in group 3 but with other household sizes. In group 1 or group 2, households with children under 6 years old only, or under 6 and age 6 to 12, or under 6, age 6 to 12 and age 13 to 17 have significantly lower pork expenditure shares than other households in group 1 or group 2. Households in group 1 or group 3 and with children at age 6 to 12 and age 13 to 17 have significantly higher pork expenditure shares than other households in group 1 or group 3. Households in group 1 and with education levels as "College or Tech. Graduates" have significantly lower pork expenditure shares than other households. In group 2 or group 3, households with annual income between $30,000 and $50,000 have significantly lower pork expenditure shares than households in other income categories.

In terms of chicken expenditure shares, household heads in group 2 and with education levels below college have higher chicken expenditure shares than households in group 2 but with other education levels. Households in group 1 or group 2 and with annual income $30,000-$39,999 have significantly higher chicken expenditure shares than households in group 1 or group 2 but with different annual income categories. Households in group 1 and with annual income $40,000-$59,999 have significantly higher chicken expenditure shares than households in group 1 but with different annual income categories. In terms of turkey expenditure share, the households in group 2 and with 2 or 4 members have significant lower turkey expenditure shares than households in group 2 but with different number of members. In group 1, households with annual income $40,000-$49,999 spend significantly less on turkey than other households in group 1. In contrast, households in group 2 with annual income $40,000-$49,999 spend significantly more on turkey than other households in group 2. In group 3, households with origin as "rural" have significantly lower turkey expenditure shares than households with origin as "urban".

All the above discussions revealed the fact that demographic profiles of Canadian households such as income, education level, number of children have significant impacts in their meat purchases and more importantly, the impacts of different demographic variables on different meat purchases have been empirically measured through the demand models, which provide certain tools for simulating the changes of meat purchases in a group due to the changes of demographic profiles in that group.

Habit formation also plays an important role in total meat expenditure and individual meat expenditure shares. In all groups, the lagged meat expenditure or lagged disappearance of beef (pork, chicken, turkey, seafood) has a significant impact on the current meat expenditure or current meat expenditure share of beef (pork, chicken, turkey, seafood). The prices of different types of meats also have significant impacts on total meat expenditure and individual meat expenditure shares. The results of various elasticities are reported in Table 4.17.

Comparing the elasticities from the time period 2002-2007 and the time period 2004-2007, most of the own-price elasticities of beef, pork, chicken, turkey in all groups appear to be larger after 2003. Group 3 ("somewhat concern group") has the largest increase in beef and chicken own-price elasticities of demand. The increases in own-price elasticities of beef after 2003 may be the result of the BSE outbreak in 2003 in Canada. Among the cross-price elasticities that are statistically significant, the beef demand elasticities with respect to other meat prices are negative after 2003, suggesting that people are reluctant to use beef as a substitute for other meats. The substitution pattern among different types of meats is also revealed in the Allen-Uzawa elasticity of substitution (AUES). AUES between beef and pork, beef and chicken increases for group 1 ("confident group") and group 3 ("somewhat concerned group") after 2003, implying that a relative change of beef prices with respect to pork (chicken) prices can bring about more substitution between beef and pork (chicken) for group 1 ("confident group") and group 3 ("somewhat concerned group").

Table 4.17 Elasticities from Demand Model Based on Panel Data of Household Survey and Predictive Difference Approach[a]

Elasticity type[c]		Group 1		Group 2		Group 3		Group 4	
		2004-2007	2002-2007	2004-2007	2002-2007	2004-2007	2002-2007	2004-2007	2002-2007
Elasticity across two stages	Beef demand-Beef price	-0.940 (-5.190) ***	-0.660 (-4.020) ***	-0.900 (-4.450) ***	-0.800 (-4.450) ***	-1.040 (-4.310) ***	-0.420 (-1.950) *	-0.480 (-0.570)	-1.180 (-1.700)
	Pork demand-Pork price	-1.430 (-28.110) ***	-1.340 (-27.440) ***	-0.980 (-20.270) ***	-0.920 (-20.100) ***	-0.780 (-11.360) ***	-0.720 (-11.520) ***	-1.400 (-11.670) ***	-1.340 (-13.270) ***
	Chicken demand-Chicken price	-1.090 (-6.320) ***	-0.670 (-4.500) ***	-1.090 (-5.760) ***	-0.950 (-6.190) ***	-1.200 (-5.250) ***	-0.470 (-2.530) ***	-1.280 (-2.410) ***	-1.730 (-3.980) ***
	Turkey demand-Turkey price	-0.980 (-5.450) ***	-0.800 (-4.670) ***	-0.690 (-4.020) ***	-0.680 (-4.140) ***	-0.310 (-1.700)	-0.440 (-2.460) ***	-2.100 (-3.660) ***	-1.960 (-3.770) ***
	Seafood demand-Seafood price	-1.050 (-13.640) ***	-1.040 (-15.610) ***	-0.330 (-3.720) ***	-0.410 (-5.380) ***	0.010 (0.010)	-0.280 (-2.730) ***	-1.060 (-5.920) ***	-1.280 (-8.530) ***
	Beef demand-Pork price	-0.190 (-3.730) ***	-0.190 (-3.960) ***	-0.180 (-3.710) ***	-0.070 (-1.610)	0.130 (1.900) *	0.140 (2.230) **	-0.140 (-1.030)	-0.150 (-1.260)
	Beef demand-Chicken price	-0.420 (-2.870) ***	-0.670 (-5.070) ***	-0.110 (-0.670)	-0.060 (-0.420)	0.250 (1.170)	-0.220 (-1.230)	-1.140 (-1.580)	-0.890 (-1.500)
	Beef demand-Turkey price	-0.010 (-0.180)	0.010 (0.300)	-0.060 (-1.340)	-0.060 (-1.340)	-0.040 (-0.610)	-0.020 (-0.270)	-0.150 (-0.490)	-0.060 (-0.250)
	Beef demand-Seafood price	-0.220 (-4.100) ***	-0.160 (-3.610) ***	-0.090 (-1.630)	-0.040 (-0.940)	-0.120 (-1.730)	0.020 (0.380)	-0.220 (-0.790)	-0.350 (-1.430)
	Pork demand-Beef price	-0.360 (-3.650) ***	-0.370 (-3.900) ***	-0.350 (-3.670) ***	-0.140 (-1.580)	0.220 (1.820)	0.250 (2.170) *	-0.190 (-0.980)	-0.230 (-1.250)
	Pork demand-Chicken price	-0.150 (-1.770)	-0.060 (-0.790)	0.030 (0.390)	0.090 (1.120)	0.170 (1.580)	0.280 (2.760) ***	-0.230 (-0.710)	-0.510 (-1.910) *

	Pork demand-Turkey price	-0.070 (-3.750) ***	-0.110 (-6.830) ***	-0.010 (-0.580)	-0.040 (-2.480) ***	-0.200 (-8.810) ***	-0.130 (-6.390) ***	-0.080 (-1.000)	-0.230 (-3.460) ***
	Pork demand-Seafood price	0.230 (6.440) ***	0.220 (7.040) ***	-0.030 (-1.200)	-0.010 (-0.670)	-0.240 (-8.460) ***	-0.170 (-6.840) ***	-0.220 (-1.430)	-0.320 (-2.570) ***
	Chicken demand-Beef price	-0.490 (-2.310) **	-0.790 (-4.590) ***	-0.120 (-0.570)	-0.070 (-0.390)	0.270 (1.070)	-0.250 (-1.200)	-0.650 (-1.370)	-0.520 (-1.340)
	Chicken demand-Pork price	-0.090 (-1.720)	-0.040 (-0.790)	0.020 (0.400)	0.050 (1.150)	0.110 (1.620)	0.170 (2.800) ***	-0.090 (-0.700)	-0.200 (-1.790)
	Chicken demand-Turkey price	-0.060 (-1.080)	-0.070 (-1.520)	-0.010 (-0.210)	0.040 (0.790)	0.010 (-0.060)	0.050 (0.850)	0.150 (0.710)	0.040 (0.260)
	Chicken demand-Seafood price	-0.060 (-1.050)	-0.090 (-2.100) *	-0.130 (-2.400) ***	-0.100 (-2.190) **	0.010 (0.020)	-0.010 (-0.110)	-0.250 (-1.210)	-0.230 (-1.260)
	Turkey demand-Beef price	-0.060 (-0.180)	0.090 (0.300)	-0.450 (-1.280)	-0.440 (-1.320)	-0.240 (-0.590)	-0.110 (-0.270)	-0.380 (-0.470)	-0.180 (-0.240)
	Turkey demand-Pork price	-0.240 (-4.160) ***	-0.400 (-7.240) ***	-0.040 (-0.740)	-0.140 (-3.140) ***	-0.750 (-9.180) ***	-0.490 (-6.980) ***	-0.150 (-0.940)	-0.440 (-2.610) ***
	Turkey demand-Chicken price	-0.330 (-1.150)	-0.410 (-1.530)	-0.060 (-0.230)	0.220 (0.830)	-0.020 (-0.060)	0.290 (0.870)	0.670 (0.770)	0.200 (0.250)
	Turkey demand-Seafood price	-0.190 (-1.470)	-0.150 (-1.350)	-0.090 (-0.570)	0.010 (0.080)	0.500 (2.890) ***	0.240 (1.630)	-0.150 (-0.380)	-0.270 (-0.660)
Risk perception elasticities across two stages[b]	Beef-risk perception	-0.439 (-1.990)		-0.593 (-2.090)		-2.045 (49.260) ***		-1.285 (-36.460) ***	
	Pork-risk perception	0.462 (2.110)		0.756 (2.680)		1.965 (47.680) ***		0.847 (26.400) ***	
	Chicken-risk perception	0.225 (1.010)		0.263 (0.920)		1.136 (27.320) ***		-0.025 (0.690)	
	Turkey-risk	0.423		-0.661		-5.813		2.451	

	perception	(1.930)		(2.350)		(-140.960) ***		(72.180) ***	
Allen-Uzawa elasticity of substitution	Beef-Pork	0.770 (11.510) ***	0.640 (10.960) ***	0.380 (5.070) ***	0.640 (10.230) ***	1.470 (17.410) ***	1.190 (16.220) ***	1.210 (3.610) ***	1.610 (5.540) ***
	Beef-Chicken	0.420 (0.950)	-0.510 (-1.390)	0.990 (2.030) *	0.840 (2.140) *	1.600 (2.730) ***	-0.200 (-0.410)	-0.900 (-0.460)	0.280 (0.190)
	Beef-Turkey	1.630 (2.080) *	1.910 (2.520) ***	0.090 (0.110)	-0.160 (-0.190)	0.130 (0.120)	0.200 (0.190)	0.350 (0.110)	1.840 (0.640)
	Beef-Seafood	-0.710 (-1.710)	-0.180 (-0.510)	0.280 (0.550)	0.500 (1.080)	-0.720 (-0.990)	0.780 (1.230)	0.860 (0.850)	0.600 (0.710)
	Pork-Chicken	1.300 (16.020) ***	1.460 (22.190) ***	1.440 (17.090) ***	1.310 (19.750) ***	1.370 (14.130) ***	1.360 (16.970) ***	1.510 (7.150) ***	1.280 (7.760) ***
	Pork-Turkey	0.540 (2.980) ***	-0.420 (-2.470) ***	1.140 (5.420) ***	0.260 (1.350)	-2.890 (-10.780) ***	-1.950 (-8.220) ***	1.130 (2.010) *	-0.260 (-0.500)
	Pork-Seafood	4.360 (32.500) ***	4.190 (35.550) ***	0.980 (8.060) ***	0.850 (7.740) ***	-2.360 (-11.360) ***	-1.820 (-10.750) ***	0.890 (5.130) ***	0.750 (5.240) ***
	Chicken-Turkey	0.720 (0.800)	0.340 (0.420)	1.130 (1.220)	1.720 (2.090) *	0.750 (0.670)	1.420 (1.360)	3.890 (1.910) *	3.170 (1.790)
	Chicken-Seafood	1.110 (2.320) **	0.570 (1.420)	-0.250 (-0.430)	-0.220 (-0.440)	0.840 (1.140)	0.420 (0.640)	0.700 (1.180)	1.310 (2.660) ***
	Turkey-Seafood	-0.340 (-0.270)	-0.060 (-0.060)	0.200 (0.110)	1.160 (0.750)	7.340 (3.330) ***	3.790 (1.920) *	1.250 (0.890)	1.070 (0.780)

a: Note: due to the estimations of model during the period 2002-2003 have a high multicollinearity (condition number=241>30), the results from statistical tests may not be reliable. So we instead use the model based on whole time period and the model based on time period after BSE in 2003 to compute the elasticities. In essence, if there are no structural changes, the estimations of elasticities based on the two different time periods should be very close. The difference between the elasticity measures based on the two different time periods should imply certain structural changes due to BSE in 2003.

b. The risk perception is approximated by the predictive difference based on data from 2004 to 2007 and data from 2002 to 2007.

c: ”*,**,***” represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses.

In terms of risk perception elasticities, similar to the model results based on time series data, beef demand responds negatively to BSE risk perceptions. Other meat demand except turkey responds positively to BSE risk perceptions, implying the substitution of beef by other meats except turkey due to BSE impacts. Group 3 ("somewhat concern group") and group 4 ("report no beef-eating group") have larger and more significant risk perception elasticities than other groups, which is consistent with their high aversion to risks about beef. The predictive differences in different groups are estimated based on the predictions for the post-BSE period (2004-2007) from the model based on the period 2004-2005, the model based on the period 2006-2007 and the model based on the period 2002-2003, given the structural breaks identified in 2003, 2005.

The predictive differences are reported in Figure 4.14-4.17. The predictive differences for beef are negative in all groups. In groups 2 and 3, predictive differences for turkey are positive, and in group 4, the predictive differences for chicken are positive, suggesting the substitution of turkey for beef in group 2 and group 3 and the substitution of chicken for beef in group 4.

Figure 4.14 Predictive Differences Based on Panel Data of Group 1

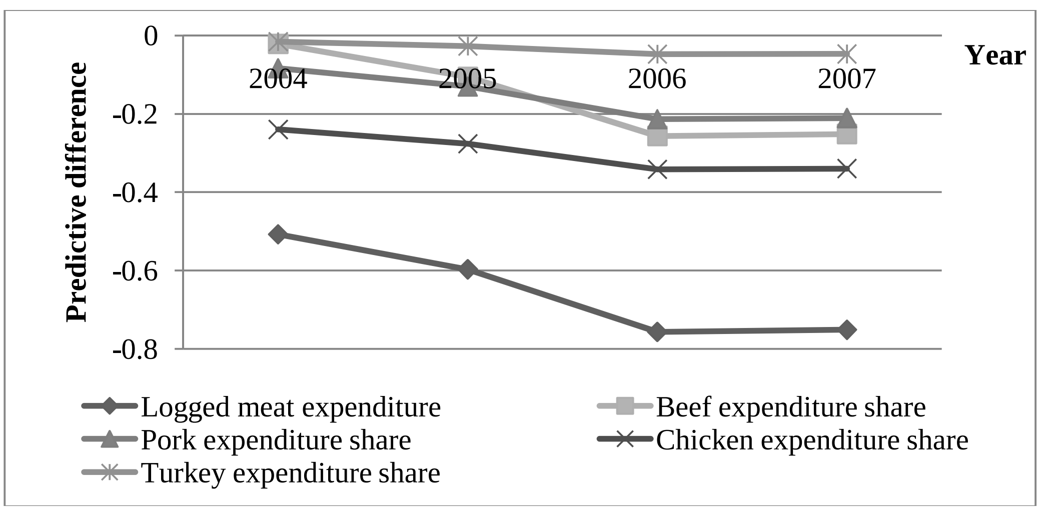


Figure 4.15 Predictive Differences Based on Panel Data of Group 2

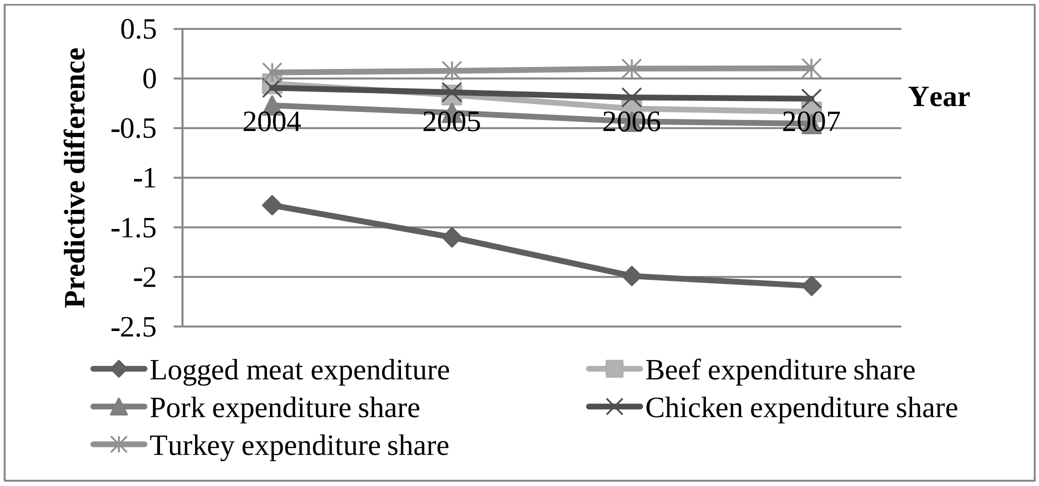


Figure 4.16 Predictive Differences Based on Panel Data of Group 3

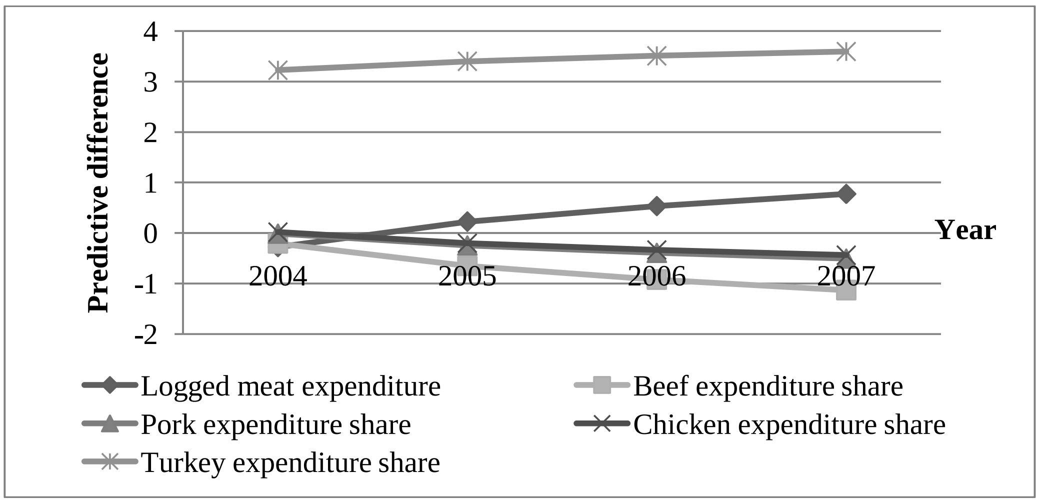
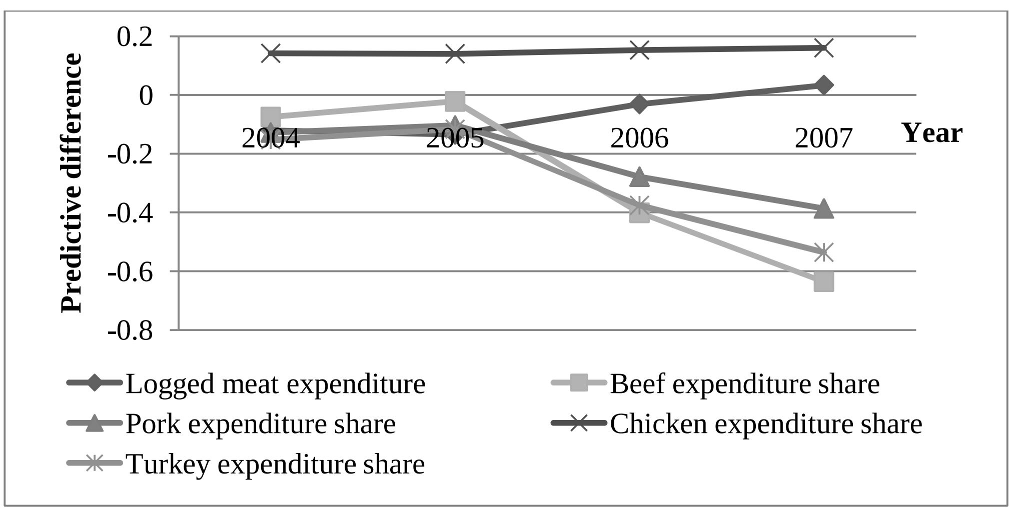


Figure 4.17 Predictive Differences Based on Panel Data of Group 4



The estimated risk perception education for each group is reported in Table 4.18. The lagged risk perceptions of BSE have a significantly positive effect on current risk perceptions about BSE on all groups, suggesting that the Prospective Reference Theory (PRT) does play a role in risk perception formation. This is different from the time series model where PRT is not supported. BSE information has a significantly negative impact on the risk perceptions in group 1 and 2, suggesting that BSE information actually decreased the risk perceptions about BSE of consumers in group 1 ("confident group") and group 2 ("neutral group"). However, the BSE information has a significantly positive impact over the risk perceptions in group 3 ("somewhat concerned group"), indicating that consumers in group 3 ("somewhat concerned group") actually feel more risk when they get more information about BSE.

Table 4.18 Results from BSE Risk Perception Equation Based on Panel Data of Household Survey and Predictive Difference Approach

Dependent variable: risk perception deviations from baseline risk approximated through predictive difference approach				
Variables inside of risk perception equation	Parameter[b]			
	Group 1 ("confident group")	Group 2 ("neutral group")	Group 3 ("somewhat concerned group")	Group 4 ("report no beef-eating group")
Lagged risk perception over BSE	0.286 (60.895) ***	0.387 (82.170) ***	0.345 (59.618) ***	0.276 (11.714) ***
Gross BSE information	-0.029 (-11.982) ***	-0.026 (-23.091) ***	0.038 (15.706) ***	0.009 (0.302)
BSE information from local media[a]	0.029 (9.483) ***	0.028 (17.613) ***	-0.037 (-12.515) ***	-0.001 (-0.035)
BSE information addressing government	-0.021 (-20.937) ***	-0.016 (-30.771) ***	0.027 (22.344) ***	0.015 (1.394)
BSE information addressing scientists	0.009 (7.332) ***	0.010 (17.261) ***	-0.012 (-10.306) ***	-0.004 (-0.300)
BSE information addressing affected producers	-0.009 (-2.169) *	-0.022 (-9.972) ***	0.014 (3.374) ***	0.0165 (0.298)
Time trend	-0.072 (-15.711) ***	-0.069 (-31.151) ***	0.088 (19.595) ***	-0.070 (-1.219)

a: All the BSE information indices are of 100 messages. The incorporation of BSE information from local media instead of national media is due to the high correlation between the gross media information about BSE and the BSE information from national media.

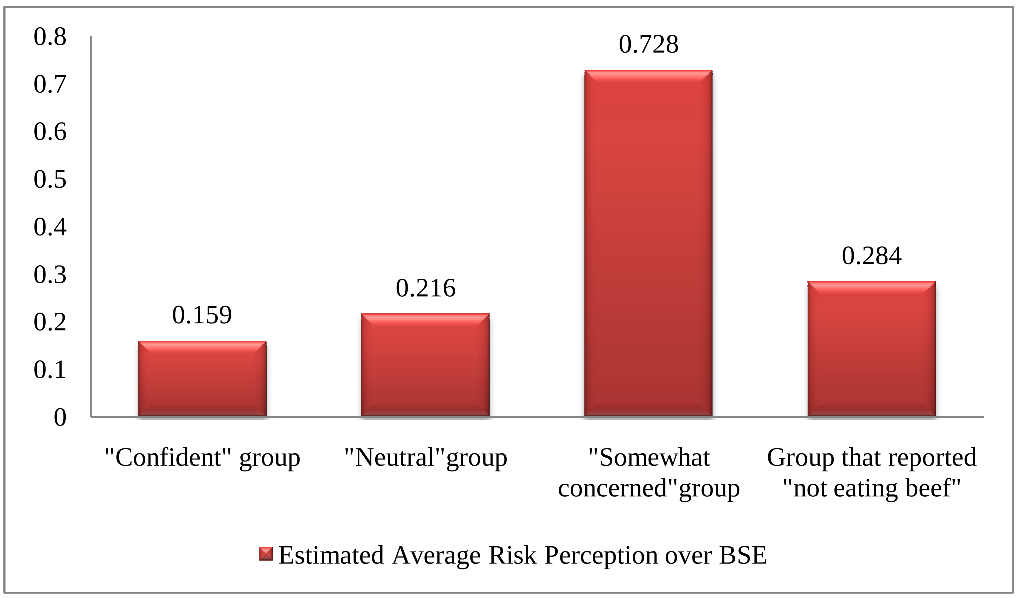
b: "*,**,***" represent 95%, 97.5% and 99% level of significance respectively.T-statistics are in parentheses.

The information from local media has a significant positive effect on the risk perceptions in group 1, 2 and the absolute values of parameters of the BSE information from local media are much larger than the parameters of the gross BSE information, implying an amplification of risk perceptions about BSE from local media which is, in magnitude, larger than the attenuation effect from gross media information of BSE in group 1 (“confident group”) and group 2 (“neutral group”). In contrast, the information from local media has an attenuation effect on risk perceptions in group 3 (“somewhat concerned group”). The information addressing government or BSE affected producers has a significantly negative impact on risk perceptions in groups 1 and 2, indicating the important role of government in risk elimination and consumers’ sympathy about BSE affected Canadian producers in groups 1 and 2. The information addressing scientists has a significantly positive impact on risk perceptions in groups 1 and 2, implying that the messages addressing scientists amplified consumer risk perceptions in groups 1 and 2. To the contrary, the information addressing government or BSE affected producers has a significantly positive impact on risk perceptions in group 3 (“somewhat concerned group”) while the information addressing scientists has a significantly negative impact on risk perceptions, suggesting that consumers in group 3 (“somewhat concerned group”) trust scientists but distrust government in their risk perception formations. Therefore, the “sympathy” or “altruism” of consumers to BSE affected Canadian producers is only present in group 1 (“confident group”) and group 2 (“neutral group”). The same information indices have different impacts on risk perceptions for different groups, which might be due to the difference of risk attitudes in beef eating in these groups.

The fact that both the quantity of BSE information (gross BSE information) and the content of BSE information (information addressing government, scientists and producers and information from local media) affect consumer risk perceptions implies the SARF in groups 1, 2 and 3. For group 4 (“reporting no beef eating group”), the gross media information of BSE was the only significant variable in risk perception equation. The time trend has a significantly negative impact on risk perceptions in groups 1 and 2, implying a reference point effect where people have adjusted their risk perceptions based on their initially perceived risk levels, a similar result to that from the time series model. However, in group 3 (“somewhat concerned group”) model, the time trend actually has a significantly positive impact in risk perceptions and therefore, the risk perceptions in group 3 (“somewhat concerned group”) are getting larger over time.

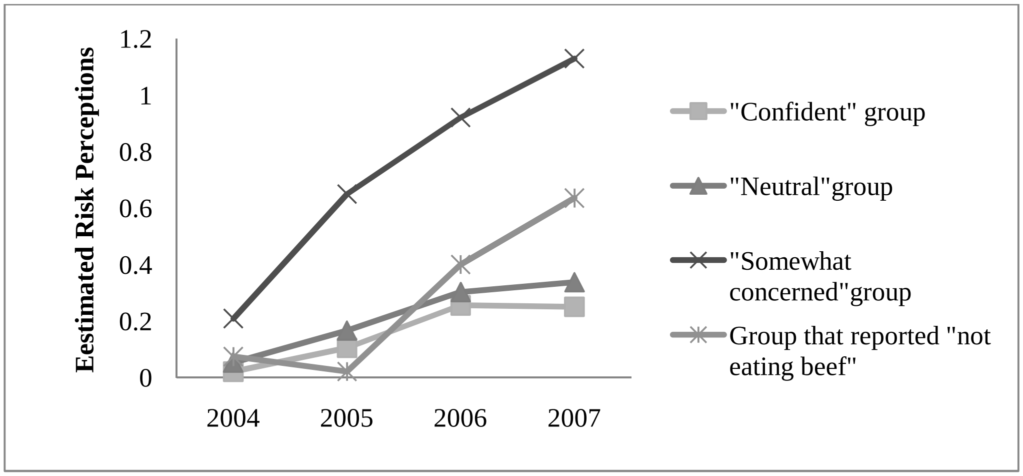
The estimated average risk perceptions of different consumer groups are shown in Figure 4.18. Comparing different consumer groups, group 3 (“somewhat concerned group”) and 4 have the highest and second highest average risk perceptions about BSE.

Figure 4.18 Estimated Average Risk Perceptions over BSE Based on Panel Data of Household Survey and Predictive Difference Approach



The changes in risk perceptions over time are reported in Figure 4.19. The graph above shows that group 3 (“somewhat concerned group”) and group 4 (“reporting no beef eating group”) have larger increases in BSE risk perceptions from 2004 to 2007 as compared to group 2 (“neutral group”) and group 1 (“confident group”), implying that consumers who had high aversions to risks associated with beef-eating and consumers who responded not eating beef in the survey feel much more risky about beef-eating due to BSE than consumers in the “confident group” and “neutral group”. Further, the graph shows that consumers in different groups have different magnitudes of amplification of risk associated with BSE.

Figure 4.19 Risk Perception of BSE over Time Based on Panel Data of Household Survey and Predictive Difference Approach



4.3.4 Tests for Hypotheses

The hypotheses tested are as follows:

1. The Social Amplification of Risk Framework (SARF). This hypothesis has been confirmed by the significance of the parameters of the gross information index about BSE and content information indices about BSE represented by the source credibility index (BSE information from local media) and subject indices (including BSE information addressing government, scientists or BSE affected Canadian producers) in the risk perception equations of group 1 (“confident group”), group 2 (“neutral group”), group 3 (“somewhat concerned group). Group 4 (“report no beef-eating” group) only supports the impacts of gross BSE information on risk perceptions.
2. Prospective Reference Theory (PRT). By checking the significance of parameters of lagged risk perceptions over BSE in risk perception equations, PRT is confirmed for all groups.
3. Self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998). The hypothesis of self-adjustment over time is proved by the significant parameters of time trend variable in risk perception equations. Further, the negative parameters of the time trend variable in the risk perception equations of group 1 (“confident group”) and group 2 (“neutral

group") indicate that consumers in group 1 and group 2 tend to go back to their initial perceived risk. In contrast, the positive parameter of the time trend variable in the risk perception equation of group 3 ("somewhat concerned group) suggests that consumers in group 3 tend to have larger risk perceptions over time.

4. "Sympathy" or "altruism" of Canadian consumers to BSE affected Canadian producers. This hypothesis is only supported in group 1 ("confident group") and group 2 ("neutral group") by the significant negative parameters of the BSE information index addressing BSE affected Canadian producers in the risk perception equations for those groups. In group 3 ("somewhat concerned group) and group 4 ("report no beef-eating" group), however, the BSE information index addressing BSE affected Canadian producers enlarged their risk perceptions.
5. The possible structural breaks at the time period when BSE was discovered in Canada are tested parametrically and non-parametrically. Parametrically, a likelihood ratio test is applied to the two-stage demand system based on annual group panel data and the results suggest structural breaks in 2004 and 2006 in all groups. Non-parametrically, a Friedman test and a Kendall's W test are applied for both the annual and quarterly data of different groups. The tests based on annual data suggest structural breaks in 2003, 2004, 2005 and 2006. Further, based on quarterly data, structural breaks in the first quarter, 2004 and first quarter, 2005 and the third quarter of 2006 are identified corresponding to the time periods when several BSE-infected cows were found in Canada.
6. As shown by the significance of parameters associated with lagged meat disappearances and lagged meat expenditure in Tables C.5 to C.8, habit formation does have a significant effect in individual meat expenditure shares and total meat expenditure.
7. The effects of demographic variables are confirmed by the significance of parameters associated with demographic variables in the two-stage demand system.

4.4 Comparison with Previous Studies

A comparison to price and food safety elasticities in the existing literature is shown in Table 4.19 and 4.20. In terms of price elasticities, the estimates from this study are within the range of previous studies. The disaggregated studies of household panels by their risk attitudes revealed more information about the connection between risk attitudes and purchase behaviour of Canadian households. The estimates of most food safety elasticities from state-space approach are within the ranges of elasticities from other studies. However, the food safety elasticities from the predictive difference approach are higher than the previous studies in Canada, possibly due to the differences in time periods from which models are based, the differences in definitions of food safety elasticities, model specifications and estimated methods. The elasticities from this study are based on the quarterly time series data from 1978 to 2005 and the household survey data from 2002 to 2007. These data are sufficient for tracking the BSE-led structural changes in consumer preferences by including the time period when the first North-American BSE infected cow was found in 2003, and the period when several following BSE-infected cows were found in either Canada or the U.S. The models based on both time series data and panel data provide more robust results than the models based on any single data such as the work of Burton and Young (1996), Flake and Patterson (1999), and Piggott and Marsh (2004). Further, the demand models in this paper provide empirical methods for estimating risk perceptions of BSE based on various quantitative and qualitative media coverage about BSE. The approach to estimating risk perceptions of BSE, though somewhat arbitrary, does offer certain insights about how people adjust their risk perceptions about BSE or other similar risky events over time.

The estimations of the panel data model show that the demographic variables play important roles in meat demand. This result is consistent with other findings. For example, the demographic variables may also work as explanatory variables that affect the consumers' participation decisions (Jones 1989; Blaylock and Blisard, 1991; Jones and Yen, 2000; Marsh et al., 2004). Age or gender has been identified as a significant variable affecting consumer decision-making (Heien and Wessells, 1988; Yen and Huang, 2002; Wang et al., 2004). Household size is a significant explanatory variable in consumer demand (Wang et al., 2004). Education level was also suggested to be a big factor in consumer demand (Wang et al., 2004). Lomeli (2005) also found that the food safety elasticities varied with different levels of education of sample correspondents.

Table 4.19 Own-Price Elasticities of Beef, Pork and Chicken

Meat type			**Beef**	**Pork**	**Chicken**
Previous Estimates (Canada)					
Tryfos and Tryphonopoulus (1973)			-0.521	-1.049	-0.87
Hassan and katz (1975)			-0.767	-0.955	-0.564
Hassan and Johnson (1979)			-0.453	-0.836	-0.732
Young (1987)			-0.480	-0.660	-0.470
Coleman and Meilke (1988)			-0.460	-0.780	
Alston and Chalfant (1991)			-0.660	-0.740	-0.740
Chalfant, Gray and white (1991)			-0.403	-0.591	-0.769
Chen and Veeman (1991)			-0.770	-0.820	-0.950
Reynolds and Goddard (1991)			-0.736	-0.676	-0.334
Goddard and Cozzarin (1992)			-1.080	-0.100	-0.320
Moschini and Vissa (1993)			-0.837	-0.635	-0.422
Cranfield and Goddard (1999)			-0.556	-	-
Eales (1996)			-0.810	-0.860	-0.450
Xu and Veeman (1996)			-0.797	-0.694	-0.412
Goddard et al (2004)			-0.455	-0.154	-0.602
Lomeli (2005)			-0.428	-0.363	-0.463
Previous Estimates (US)					
Chavas (1983)			-0.974	-0.735	-0.5
Wohlgenant (1985a)			-1.140	-	-
Menkhaus et al. (1985)			-1.166	-0.691	-0.841
Dahlgran (1987)			-0.659	-0.584	-0.602
Chen (1998)			-0.951	-0.993	-0.62
Eales and Unneveher (1988)			-0.570	-0.762	-0.276
Moschini and meilke (1989)			-1.050	-0.840	-0.100
Jensen and Schroeter (1992)			-1.250	-	-
Goddard et al. (1992)			-0.470	-0.120	-0.460
Alston and Chalfant (1993)			-0.980	-0.170	-0.940
Moschini and Vissa (1993)			-0.837	-	-
Brester and Schroeder (1995)			-0.490	0.010	0.190
Hahn (2001)			-0.827	-0.725	-0.300
Huang and Lin (2000)			-0.354	-0.686	-
John (2007)	Canada 1980:1-2003:1		-0.401		
	U.S. 1980:1-2003:1		-0.596		
	Canada 1980:1-2005:4		-0.387		
	U.S. 1980:1-2005:4		-0.309		
	North America		-0.147		
This study	Predictive difference approach based on quarterly time series data, 1978:1-2003:1		-0.500	-0.510	-0.480
	Predictive difference approach based on quarterly time series data, 1978:1-2005:4		-0.450	-0.470	-0.480
	State-space	Model 1	-0.880	-0.900	-0.950

	approach based on quarterly time series data, 1978:1-2005:4				
		Model 2	-0.760	-0.820	-0.900
		Model 3	-0.810	-0.860	-0.920
	Predictive difference approach based on panel survey data, 2002-2007	Group 1 or "confident group"	-0.660	-1.340	-0.670
		Group 2 or "neutral group"	-0.800	-0.920	-0.950
		Group 3 or "somewhat concerned group"	-0.420	-0.720	-0.470
		Group 4 or "report no beef-eating group"	-1.180	-1.340	-1.730

Table 4.20 Food Safety Elasticities for Beef, Pork and Chicken

Study	Country	Functional Form		Commodity		
				Beef	Pork	Chicken
Burton and Young (1996)	UK	AIDS		-0.045	0.016	0.001
Strak (1998)	UK	AIDS		-0.005	0.002	n/a
Flake and Patterson (1999)	US	AIDS		-0.013	0.014	0.014
Herrmann et al. (2002)	Germany	Semi-Log		-0.074	n/a	n/a
Piggott and Marsh (2004)	US	G-AIDS (Generalized AIDS)		-0.014	-0.013	-0.025
Goddard et al. (2004)	Canada	TransLog		0.001	0.007	-0.005
		AIDS		0.003	0.011	-0.023
		GBC(Generalized Box-Cox)		-0.003	0.003	-0.008
Lomeli (2005)	Canada	GBC		0.001	-0.002	0.017
This study[a]	Canada	Predictive difference approach based on doublelog-TransLog two stage demand system and quarterly time series data		-0.220	-0.004	0.007
		State-space approach based on doublelog-TransLog two stage demand system and quarterly time series data	Model 1	-0.030	0.020	0.080
			Model 2	-0.020	0.020	0.070
			Model 3	-0.001	0.010	0.020
		Predictive difference approach based on doublelog-TransLog two stage demand system and panel survey data	Group 1	-0.440	0.460	0.220
			Group 2	-0.590	0.760	0.260
			Group 3	-2.040	1.960	1.140
			Group 4	-1.280	0.850	-0.020

a: The food safety elasticities from this study are represented by elasticities of risk perceptions of BSE.

4.5 Chapter Summary

This chapter discussed Canadian consumers' reactions to BSE or mad cow disease. Two types of datasets are applied in empirical analysis. One is quarterly time series data including meat disappearance, prices of meats, per capital disposable income and BSE information in Canada. The other dataset is a sub-sample of Nielsen Homescan™ household panel data including meat expenditure, prices of meats, BSE information in Canada and various demographic profiles of households such as region, language, household size, age and appearance of children, household head age, household head education, annual income and origin. This sub-sample data is further clustered into three groups according to the responses to risk perception and attitude questions about beef-eating. The first group is identified as a "confident group" because they are relatively confident about beef-eating. The second group is named as "neutral group" because they have neutral responses to risks related to beef eating. The third group is named the "somewhat concerned group" because they are relatively concerned about food safety risks in beef eating. A fourth group is also created for the households who responded no beef-eating in the survey questions. The four group data are then analyzed separately to compare the risk perception and demand system parameters from them. Application of both time series and panel datasets in demand analysis make the results more robust. Further, the panel data analysis from groups with different risk perceptions and attitudes about beef-eating revealed differences in their real market behaviour. Various BSE information indices are constructed to reflect both the quantity and quality aspects of media information, including gross media index, source credibility media indices and media subject indices. These media information indices are employed in the construction of risk perception equations based on sociological theories including the SARF and the PRT.

The risk perception equation is then evaluated through two approaches including a predictive difference approach and a state-space approach. A predictive difference approach approximates risk perceptions about BSE by the difference of predictions based on the periods before and after BSE[44] for the total meat expenditure or individual meat expenditure shares. A state-space approach estimates the risk perception equation about BSE and the demand system jointly. Both of the approaches provide empirical justification of the SARF, in which Canadian consumers' risk perceptions about BSE are amplified by both the quantity and quality of media information about BSE. The PRT is also supported by the household panel survey data but not by time series data, which might indicate that the households in sample follow a Baysian updating of their risk perceptions but the aggregate Canadian consumers might not follow such a updating. Based on different data and different consumer groups, media indices play different roles in consumer risk perceptions of BSE. Specifically, for the quarterly time series data and the panel data of group 3 ("somewhat concerned group") and group 4 ("report no beef-eating group"), the gross BSE information has an amplification effect on the risk perceptions about BSE while in the household panel data of group 1 ("confident group") and group 2 ("neutral group"), the gross BSE information plays an attenuation role for the risk perceptions about BSE. This result implies an average consumer or consumers who concern beef safety issues will feel more risky or scared after getting more BSE-related information while consumers who are confident in or not concerned much with beef safety may feel less risk even after getting more BSE-related information.

In terms of the BSE media index, for an average consumer, the BSE information from the national media plays an amplifying role in his (her) risk perception[45]. For consumer group 1 ("confident group") and group 2 ("neutral group"), the BSE information from local media amplified their risk perceptions about BSE while for group 3 ("somewhat concerned group") and group 4 ("report

[44] When there are no enough observations after BSE to estimate the risk perception equation, the whole period including before and after BSE are applied.

[45] This result comes from the risk perception estimation in state-space model based on quarterly time series data. The risk perception estimation by predictive difference approach or based on household panel data doesn't include the BSE information from national media due to its high collinearity with other BSE information (condition number=59>30). However, the risk perception estimation by state-space approach through Bayesian method can incorporate the BSE information from national media into the risk perception equation even though there is strong multicollinearity.

no beef-eating group”), the opposite effects are present. In terms of media subject indices of BSE, the model based on quarterly time series data and the predictive difference approach suggests that the BSE information addressing government or scientists plays an attenuation role on risk perceptions while the model based on quarterly time series data and state-space approach suggests these BSE information play an amplification role in risk perceptions.

For the BSE information addressing BSE affected producers, models based on quarterly time series data and panel data for group 3 (“somewhat concerned group”) and group 4 (“report no beef-eating group”) suggest that people are raising their risk perceptions of BSE while for the panel data from group 1 (“confident group”) and group 2 (“neutral group”), the BSE information addressing BSE affected producers decreases their risk perceptions. These results suggest that only consumers in group 1 (“confident group”) and group 2 (“neutral group”) trust the information from government and scientists. Consumers in group 3 (“somewhat concerned group”) and group 4 (“report no beef-eating group”) are sceptical about the information from government and scientists. Further, the “sympathy” or “altruism” effects regarding BSE affected Canadian producers due to BSE are only present in consumers who are confident in or not concerned much with beef safety issues (group 1 and group 2). The time trend variable has a negative impact on risk perceptions about BSE based on time series data (state-space approach) and the panel data of group 1 (“confident group”) and group 2 (“neutral group”), implying that for an average consumer or consumers who are confident in or not concerned much with beef safety issues, the risk perceptions about BSE are deceasing and returning to its baseline levels or reference risks. However, for group 3 (“somewhat concerned group”) and group 4 (“report no beef-eating group”), consumers have higher and higher risk perceptions of BSE over time. Both the predictive difference approach and state-space approach suggest that the quality and quantity aspects of BSE information have significant impacts on consumer risk perceptions, providing empirical evidence of the SARF. The lagged risk perceptions about BSE also play a significant role in risk perception equations based on the panel data of each group, implying the PRT.

In terms of risk perception elasticities, both the time series data and panel data revealed a negative impact of risk perceptions on beef demand and a positive impact of risk perceptions on the demand of some other meats. Group 3 ("somewhat concerned group") and group 4 ("report no beef-eating group") have larger risk perception elasticities as compared to other groups, which is consistent with their high aversions to the risks associated with beef-eating.

To further test changes in consumer preferences about meat eating[46],both parametric and non-parametric structural break tests are employed for the time series data and the panel data. The possible structural break points selected include years 2003 to 2006 based on annual data and the first quarter of 1992 (the first case of BSE found in Canada), the first quarter of 1996 (the announcement of possible relationship between BSE and human vCJD), the second quarter of 2003 (the first North American BSE-infected cow was found in Canada), the first quarter of 2004 (one BSE-infected cow was found in the U.S.), the first quarter of 2005 (2 BSE-infected cows were found in Canada) and the third quarter of 2006 (3 BSE-infected cows were found in Canada) based on quarterly data. The results suggest that there are structural breaks in beef, pork, chicken and total expenditure equations at the first quarter, 1994, the first quarter, 1996, the second quarter, 2003, the first quarter, 2004, the first quarter, 2005 and the third quarter, 2006. Therefore, the first case of BSE found in Canada in 1992 and the announcement of a relationship between BSE and human vCJD in 1996 had already imposed a significant impact on Canadian meat demand prior to any domestic animals with BSE being found. The discovery of the first domestic BSE-infected cow in 2003 and the following cases during 2004-2006 further altered consumer preferences about meat eating. The parametric structural break test based on the quarterly time series data suggested a bigger significance of the structural breaks in 1992 and

[46] The structural break tests are also a justification of the predictive difference approach because if there are no structural changes due to BSE, the predictive difference based on the data before and after BSE should only be due to the random errors in estimation. While if there are structural changes, the predictive difference will be affected by both consumer risk perceptions due to BSE and random errors.

1996 as compared to those after 2003. The non-parametric structural break tests based on panel data from 2002 to 2007 further suggested the second quarter of 2003, the first quarter of 2004 and the third quarter of 2006 presented higher magnitudes of structural changes than the first quarter of 2005.

Price elasticities are also estimated over the periods before and after BSE. The own-price elasticities of beef demand from both quarterly time series data and household panel data are getting larger after 2003, suggesting a more elastic beef demand after the BSE outbreak in Canada. The substitution elasticity between beef and chicken is significant and is getting larger after the BSE outbreak in 2003, implying that consumers may substitute more chicken for beef. A further result from the panel data model suggests that people are reluctant to substitute beef for other meats after 2003. Own-price elasticities of other meats change in different ways based on different datasets. Pork and turkey demand becomes more elastic after 2003 for the households in panel data but becomes less elastic after 2003 for the entire Canadian population. Chicken demand becomes more elastic after 2003 for the households in panel data but is stable for the entire Canadian population. The different patterns in changes of demand elasticities between household panel and the entire Canadian population might be due to the difference of demographic profiles between them. Comparing the elasticities from different consumer groups, beef and chicken demand are the most elastic in group 3 (“somewhat concerned group”) after the BSE outbreak in 2003, suggesting that consumers in group 3 are more prone to shifting from beef consumption as compared with other groups. This is also shown in the Allen-Uzawa elasticities of substitution, where group 3 has the largest significant substitution elasticities between beef and pork and between beef and chicken.

Other variables except BSE also affect consumer demand including a time trend, seasonality, habit formation and demographic profiles. The time trend and seasonality variables play different and significant roles on different expenditure shares. Habit formation as represented by the lagged disappearance of different meats or lagged total meat expenditure also plays significant roles in explaining expenditure share for different meats or total meat expenditure. The demographics such as region, household size, age and appearance of children, household head age, household head education, household income and origin also play significant roles in the panel data model of each group. These results have been discussed in detail in the panel data model for each group.

In summary, in this chapter consumer risk perceptions of BSE were empirically evaluated through a demand system incorporating a risk perception equation for BSE derived from sociological theories such as SARF and PRT. The dynamics of risk perceptions of BSE have been tracked and compared by a predictive difference approach and a state-space approach. Therefore, the material reported in this chapter represents initial work to apply sociological frameworks such as SARF and PRT in consumer risk perception and demand analysis and provides a guide to how to estimate consumer risk perceptions through market observable data.

Chapter 5 Canadian Cow-calf Producers' Behaviour with BSE Impacts

5.1 Introduction

Most previous studies of BSE have focused on the analyses of BSE impacts on international beef trade between Canada and other countries (Cox et al., 2005; Marsh et al., 2005; Mattson and Koo, 2005; Miljkovic, 2006; Sparling and Caswell, 2006; John, 2007; Rude and Carlberg, 2007). Some studies have discussed the impacts of BSE outbreaks on Canadian producers' income (Mitura and Di Pietro, 2004). There are few studies which have focused on cow-calf producers' reactions to BSE outbreaks in Canada except in the context of the entire beef industry (Love, 2005; John, 2007). These studies, however, haven't incorporated risk perceptions about BSE into the behavioural equations explaining cow-calf farmer behaviour. The role of cow-calf producers in the Canadian beef supply chain is critical and an examination of the possible relationship between risks (risk perceptions) and real market behaviour of cow-calf producers is important in the context of BSE. Cow-calf producers represent the beginning of the beef supply chain and they suffered directly from the evaporation of slaughter cattle demand post BSE. Second, cow-calf producers' behaviour is subject to their own risk perceptions, which in turn, may have been affected by the market outcomes of BSE. Models of cow-calf producers' behaviour can reveal these relationships and provide an indication about the role of BSE in cow-calf producers' risk perceptions and their revealed behaviour. In reality, the impacts of BSE may be measured through price effects and through responses to media coverage about BSE.

To evaluate Canadian cow-calf producers' risk perceptions about BSE and their market behaviour, six sections are included in this chapter. The second and the third sections are used for the analyses of cow-calf farmer behaviour based on time series data and panel data respectively. In each of these sections, data are described first in terms of their sources, generation procedures, distributions, and demographic profiles. In the second part of each section, structural break tests are used for the second quarter of 2003 (i.e. when the first domestic BSE-infected cow was found in Canada)[47]. In the third part of each section, beef cow inventory and slaughter cow supply equations are estimated and producers' risk perceptions about BSE are evaluated using a predictive difference approach and a state-space approach. In the third and fourth sections of this chapter, the results of hypothesis testing are reported and discussed. In the fifth section of this chapter, a comparison with previous studies about cow-calf producers' behaviour under BSE impacts is made. A summary of this chapter is provided in the final section.

5.2 Cow-Calf Farmer Model Based on Time Series Data

5.2.1 Time Series Data

The time series data include data for January beef cow inventories (annually,1931-2008), January dairy cow inventories (annually,1931-2008), number of cows slaughtered domestically (monthly, 1970-2008), imports and exports of slaughter cows (monthly, 1972-2008[48]), bank rates (monthly), interest rates (1935-2009), feed grain prices (quarterly, 1959-2008), feeder calf prices (quarterly, 1940-2008), slaughter cow prices (quarterly, 1960-2008), producer subsidy estimates (annually, 1979-2008), and media information on BSE available to Canadian producers (1990-2008). The data are collected from various sources which are reported in Appendix B. The slaughter cow supply is calculated as the sum of numbers from domestic slaughtering and exports of slaughter cows. The equations for Canadian beef cow inventory (equation 3.50, 3.51) and slaughter cow supply (equation 3.57, 3.58) are usually estimated over quarterly, semi-annual or annual data (Martin and Haack, 1977; Coleman and Meilke, 1988; Cranfield, 1995; Mbaga, 2000; John, 2007). Because January beef cow inventory data in Canada are annual, annual beef cow inventory equations are estimated.

[47] Other periods related to BSE are also tested for structural breaks including the first quarter, 1992 (the first BSE-infected cow was found in Canada), the first quarter, 1996 (the possible relationship between BSE and human vCJD was announced by the U.K. government), the first quarter of 2004 (one BSE-infected cow was found in the U.S.), the first quarter of 2005 (2 BSE-infected cows were found in Canada) and the third quarter of 2006 (3 BSE-infected cows were found in Canada).

[48] Because the data about slaughter cow exports are only available after 1972, slaughter cow supply can only be computed after 1972.

The slaughter cow supply equations are estimated using quarterly data. The price ratios between slaughter cow prices (feeder calf prices) and feed grain prices are used (Kulshreshtha and Wilson, 1974; Rucker et al., 1984; Rude et al., 2007) for the estimations of beef cow inventory and slaughter cow supply equations. The expectations of price ratios are approximated by the three-period moving averages of price ratios (Chavas and Kraus, 1990). As explained in Chapter 4, there are other advanced techniques to constructing price expectations. However, those approaches will add the complexity of model estimations considering the fact that an unobservable variable representing the risk perceptions about BSE is incorporated into the price expectation formation. The squared standard deviations (SSD) of price ratios are computed by the squared differences between the real price ratios and the expected price ratios. In the quarterly slaughter cow supply equations, the annual beef/dairy cow inventories are converted to quarterly data by assuming the inventory numbers of beef/dairy cows are the same for all four quarters of the same year[49]. In other words, the annual inventory number represents the quarterly inventory number for that year. Bank rates are converted to quarterly/yearly data by simple average of monthly rates within that quarter/year. Because of the difference in production structures in cow-calf production between Western Canada and Eastern Canada, the time series models will analyze the beef cow inventory and slaughter cow/bull supply equations in Western Canada and Eastern Canada separately (Martin and Haack, 1977; Coleman and Meilke, 1988; John, 2007).

The media information about BSE comes from national media including the Globe and Mail and National Post, and regional media including the Western Producer, Country Guide, Manitoba Co-operator and Ontario Farmer. Similar to the construction of various media indices in the consumer chapter, the national media index and the subject indices about BSE are established. The gross media index for a certain region is calculated as the sum of BSE information from

[49] Other methods of conversion are also tried including the linear interpolation and the use of January inventories of current year as the inventories of 3rd and 4th quarters of previous year the inventories of the 1st and 2nd quarter of current year. These two methods didn't show any improvement of model fit or the significant levels of inventory variable in slaughter cow supply equations.

national media and from the media in that region. The subject indices for BSE include BSE information focused on government, scientists and producers. All the media indices are constructed quarterly. The descriptive analyses for variables are reported in Table 5.1.

Table 5.1 Descriptive Analysis of Time Series Data for Western and Eastern Canada, 1970-2008

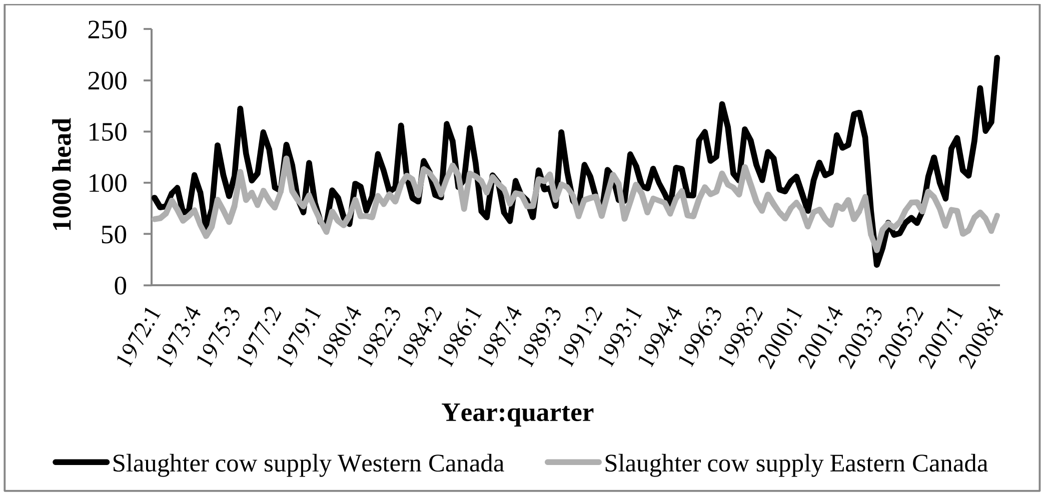
Variables / Statistics / Region	Western Canada			Eastern Canada		
	Mean (std. error)	Min.	Max.	Mean (std. error)	Min.	Max.
Slaughter cow supply (1000 head)	103.990 (31.910)	19.890	221.990	80.590 (16.490)	34.180	123.800
Beef cow inventory (1000 head)	2511.030 (1186.95)	403.400	4580	506.820 (208.170)	98.500	850.700
Dairy cow inventory (1000 head)	565.260 (317.420)	223	1255.700	1593.740 (568.040)	739.800	2428.400
Producer subsidy estimates ($ per metric tonne)[a]	163.420 (125.010)	8.500	588.500	163.420 (125.010)	8.500	588.500
Price of feeder calves ($/100 lbs)	61.770 (45.520)	5.640	163.240	53.600 (43.700)	2.900	154.310
Price of slaughter cows ($/100 lbs)	39.180 (16.890)	13.230	69.210	41.060 (17.550)	13.660	74.550
SSD of ratios of slaughter cow prices over feed prices (100%)	3.124 (0.290)	0.001	22.263	1.761 (0.190)	0.001	10.820
SSD of ratio of feeder calf prices over feed prices (100%)	10.716 (1.163)	0.004	91.114	7.202 (0.820)	0.001	53.679
Price of feed grain (Corn for Eastern Canada and Barley for Western Canada) ($ per metric tonne)	59.330 (46.800)	6	238.590	70.060 (44.740)	16	252.050
Bank rate (percentage)	5.370 (3.590)	1.500	17.930	5.370 (3.590)	1.500	17.930
Gross producer BSE information	77 (173)	0	800	61 (145)	0	768
Producer BSE information addressing government	16 (38)	0	152	14 (34)	0	162
Producer BSE information addressing scientists	2 (5)	0	30	2 (4)	0	35
Producer BSE information addressing producers	5 (13)	0	58	4 (9)	0	40

a: The producer subsidy estimates are only available for Canada and therefore, are assumed to be equal between Western Canada and Eastern Canada.

The descriptive analyses reveal that Western Canada has a high average number of beef cows while Eastern Canada has a high average number of dairy cows. The average slaughter cow/bull supply in Western Canada is higher than that in Eastern Canada. The average price of feeder calves in Western Canada is higher than that of feeder calves in Eastern Canada while the average prices for slaughter cows and feed grain are lower in Western Canada. On average, Western

Canada producers received more BSE-related media information than Eastern Canada producers. The trends of different variables are illustrated by Figures 5.1 to 5.13.

Figure 5.1 Quarterly Slaughter Cow Supply (Including Domestic Slaughter Plus Export) of Western and Eastern Canada, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

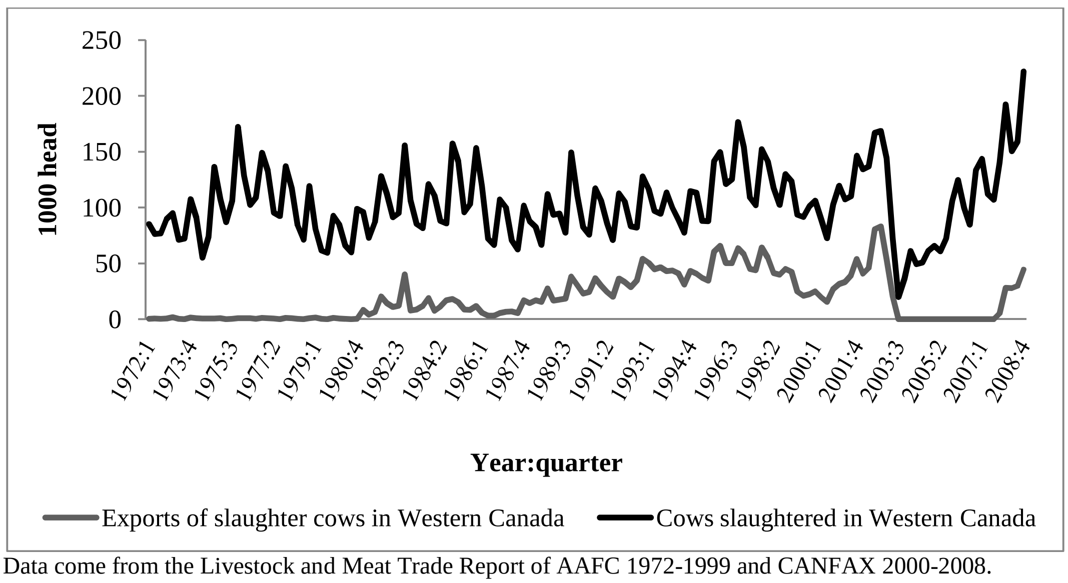
During the period 1972-2008, slaughter cow supplies in Western Canada were mostly higher than those in Eastern Canada. Before 2003, Western Canada and Eastern Canada had similar trends in slaughter cow supply. In Western Canada, slaughter cow supply reached a peak at the end of 1975, the end of 1996, the third quarter of 2002, and the end of 2008, while in Eastern Canada, slaughter cow supply reached a peak at the end of 1977 and the end of 1996.

After BSE outbreak in Alberta in the second quarter of 2003, Western Canada and Eastern Canada supplies showed different trends. For example, in Western Canada, slaughter cow supply had a sharp decline and a gradual recovery afterwards. The number of slaughter cows returned to the pre-BSE level (the level at the first quarter of 2003) at the beginning of 2007 and peaked at the end of 2008. The fourth quarter of 2008 represented the highest level of slaughter cow supply in Western Canada in history. The recovery in slaughter cow supply in Western Canada might be a joint result of domestic slaughter capacity expansion after 2003 (Rude et al., 2007, page 199) and the border re-opening of the U.S. to Canadian slaughter cows in the end of 2007 (Thoren and Tilsworth, 2009, page 10).

In Eastern Canada, the slaughter cow supply also had a sharp decline but returned the pre-BSE level (the level at the first quarter of 2003) by the end of 2005. After 2005, the number of slaughter cows to date in Eastern Canada declined again and has never returned to the pre-BSE level. The decline in slaughter cow numbers in Eastern Canada may not be a result of the BSE outbreak considering the historical downward trend in slaughter cow supply in Eastern Canada. However, the BSE outbreak might be a "final straw" for Eastern Canadian cow-calf producers. The fluctuations in slaughter cow supplies in Western and Eastern Canada may have been affected by other factors such as NAFTA (1988), WTO (1995) or Crow Rate. Further analysis is required to identify whether the BSE outbreak and other factors had any impact on slaughter cow supply in Western and Eastern Canada.

It is necessary to further examine the two components of slaughter cow supply including exports and domestic slaughter of cows, to identify the driving forces behind changes in Canadian slaughter cow supply. They are shown in Figures 5.2 and 5.3.

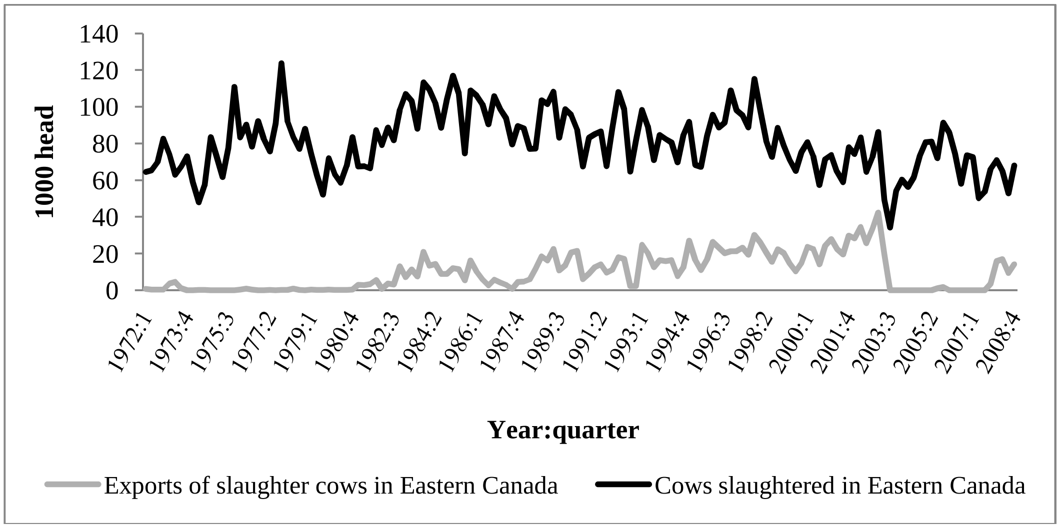
Figure 5.2 Quarterly Numbers of Cows Slaughtered and Exported in Western Canada, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

The quarterly domestic slaughter numbers of cows have a positive correlation with cow exports in Western Canada (correlation coefficient =0.53). In the post-BSE period (after the second quarter of 2003), both the numbers of cows for domestic slaughter and exports declined. The domestic slaughter numbers of cows didn't return to the pre-BSE level (the level at the first quarter of 2003) until 2007. After 2007, domestic cow slaughter expanded and reached its highest level in history at the end of 2008. Cow exports, on the other hand, did not resume until the end of 2007, when the U.S. re-opened its border to Canadian cows.

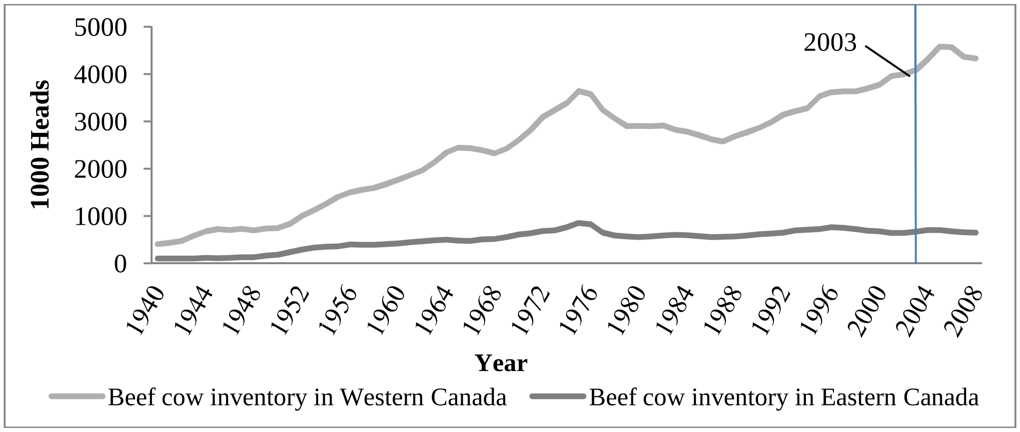
Figure 5.3 Quarterly Numbers of Cows Slaughtered and Exported in Eastern Canada, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

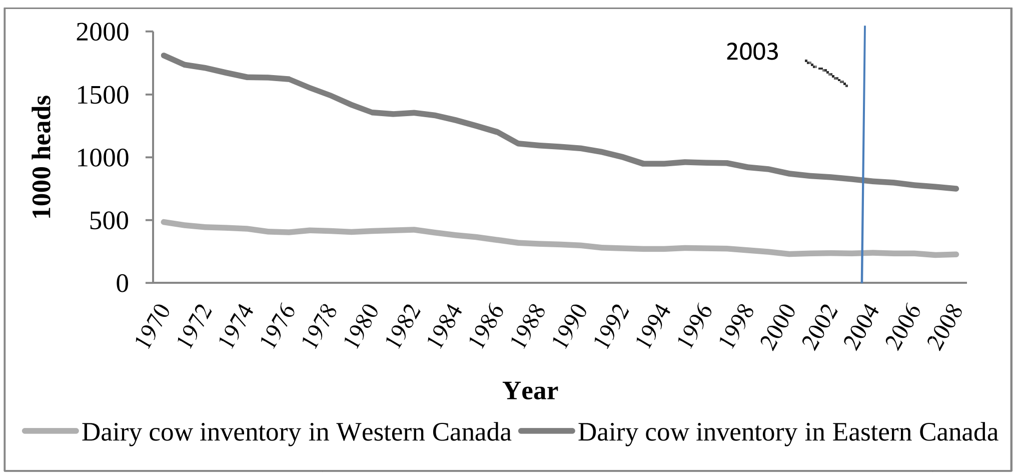
The quarterly domestic slaughter of cows also had a positive correlation with cow exports in Eastern Canada (correlation coefficient=0.30). However, it should be noted that during the whole period 1970-2008, the highest number of cows slaughtered in Eastern Canada occurred at the end of 1977 and although there was expansion of the beef cattle industry in Western Canada after 1986, the domestic slaughter of cows have never returned to the level at the end of 1977. It has taken a similar time period for the cow exports in Western and Eastern Canada to resume under the border closure to older cows from the U.S. The beef cow and dairy cow inventories in January from 1970 to 2008 are shown in Figures 5.4 and 5.5.

Figure 5.4 Annual Beef Cow Inventory (January) in Western Canada and Eastern Canada, 1940-2008



Data come from the Statistics Canada database CANSIM II Table 30032.

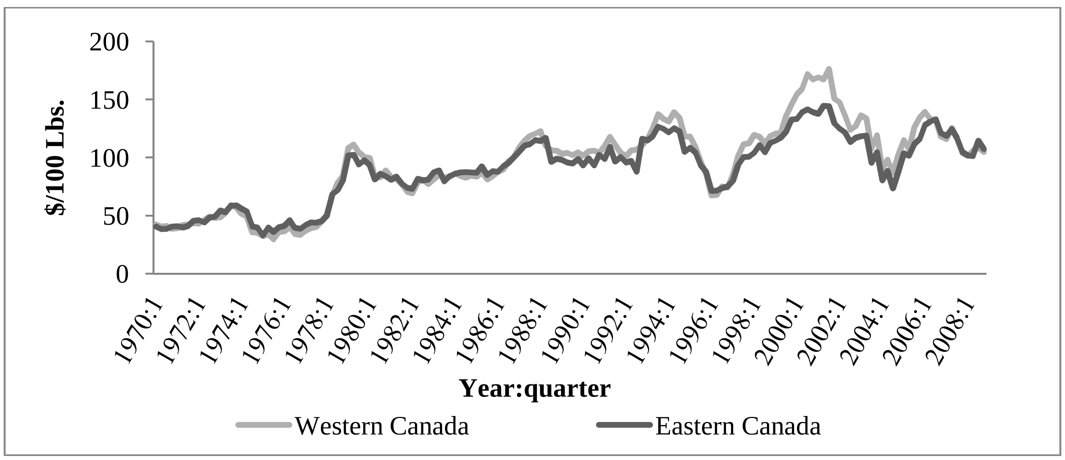
Figure 5.5 Annual Dairy Cow Inventory (January) in Western Canada and Eastern Canada, 1940-2008



Data come from the Statistics Canada database CANSIM II Table 30032.

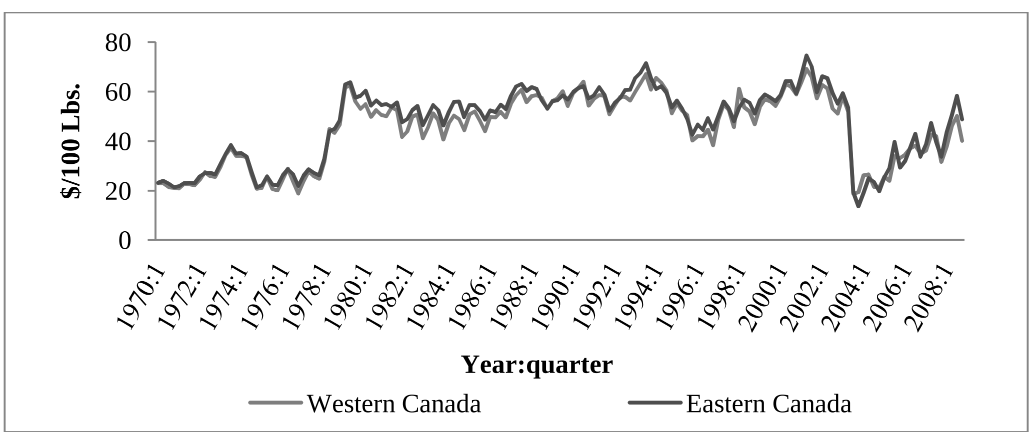
Beef cow inventories in both Western Canada and Eastern Canada reached a peak in 1975 and declined between 1975 and 1986. After 1986, beef cow inventories started to climb in both regions until 2004 or 2005 and then declined again. The rise of beef cow inventories in Western Canada might be due to the decreases in the Crow Rate (Crow's Nest Freight Rate or Crow Benefit subsidy) before 1995 and the final elimination of Crow Rate in 1995, which added to the cost of grain transportation and led cow-calf producers to increase their feed use in cow production (Coghill and Brown, 2009). An increase in beef cow inventory is present in Western Canada in 2004 and 2005 due to the decrease of slaughter cow demand. The increase in beef cow numbers in Eastern Canada is relatively small given the high percentage of dairy cow herds in Eastern Canada. Western Canada had its highest beef cow inventory in 2005 and showed bigger fluctuations in beef cow inventory as compared to Eastern Canada. In terms of dairy cow inventories, there are many more dairy cows in Eastern Canada as compared to Western Canada. The numbers of dairy cows in both Western Canada and Eastern Canada are declining over time and the decrease in dairy cow inventories in Eastern Canada is faster as compared to that in Western Canada. There are no sharp changes in dairy cow inventories in either Western Canada or Eastern Canada in 2003. The trends in prices of feeder calves, slaughter cows, feed grains, the squared standard deviations (SSDs) of price ratios and other variables are illustrated in Figures 5.6 to 5.13.

Figure 5.6 Quarterly Prices of Feeder Calves in Western and Eastern Canada, 1970-2008



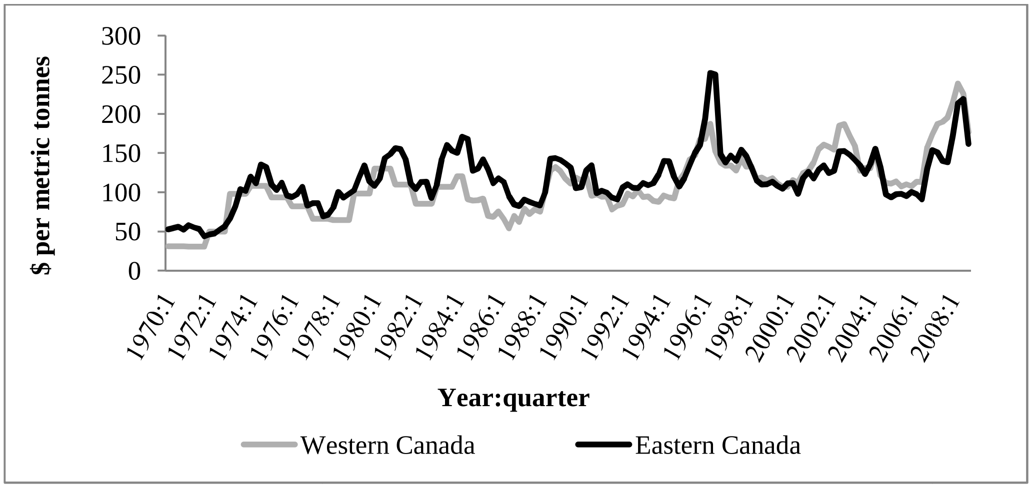
Data come from CANSIM, Livestock and Meat Trade Report 1970-1999 and CANFAX 2000-2008 (Appendix B)

Figure 5.7 Quarterly Prices of Slaughter Cows in Western and Eastern Canada, 1970-2008



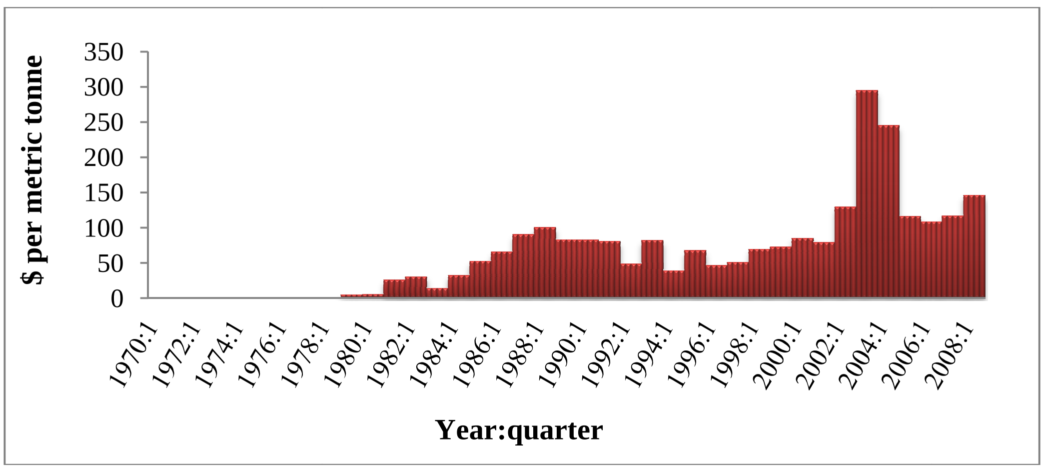
Data come from CANSIM, Livestock and Meat Trade Report 1970-1999 and CANFAX 2000-2008 (Appendix B)

Figure 5.8 Quarterly Prices of Feed in Western and Eastern Canada, 1970-2008



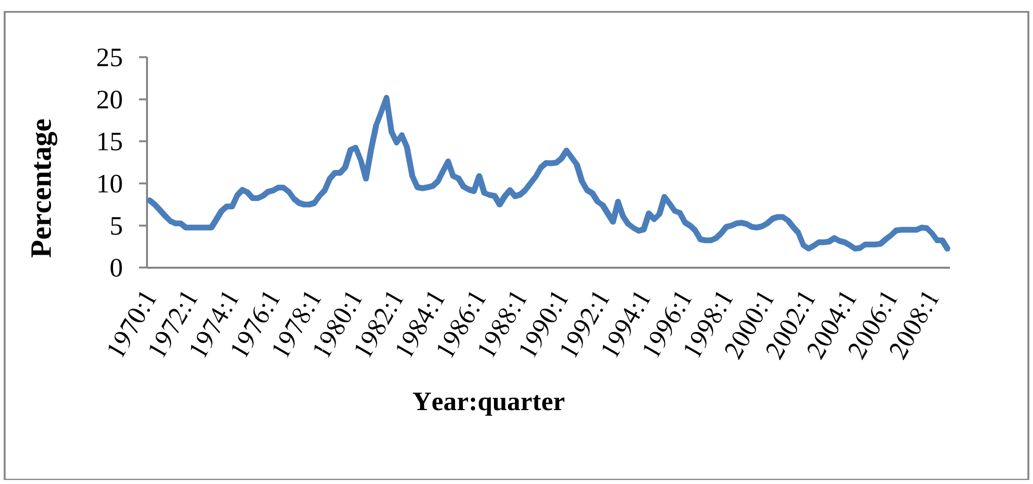
Data come from CANSIM 1970-1999 and CANFAX 2000-2008 (Appendix B)

Figure 5.9 Annual Producer Subsidy Estimates, 1979-2008



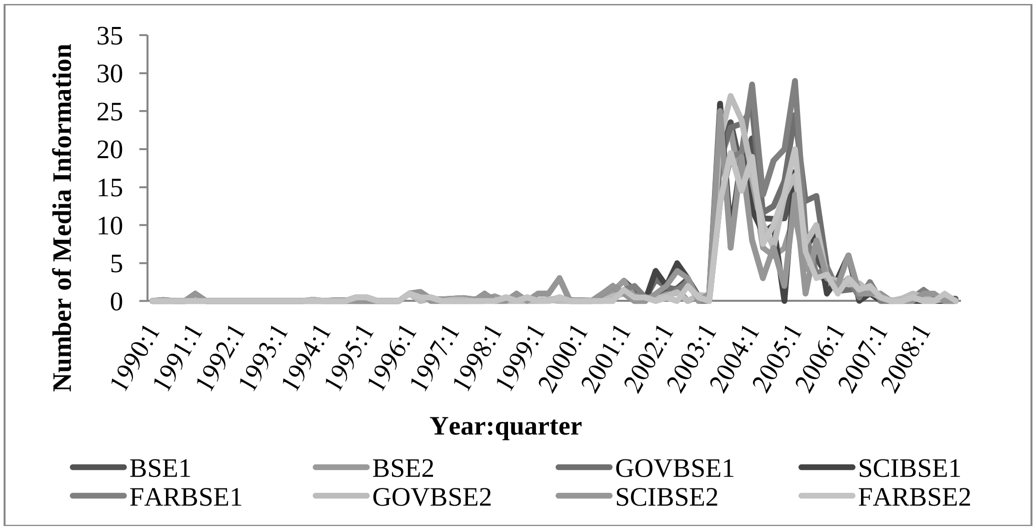
Data come from OECD (1979-2008)

Figure 5.10 Annual Bank Rates (Percentage), 1970-2008



Data are CANSIM II (2006)

Figure 5.11 Quarterly BSE Media Indices, 1990-2008



Data are from national and regional media (Appendix B)

Figure 5.12 Squared Standard Deviations (SSDs) of Slaughter Cow and Feeder Calf Price Ratios in Western Canada

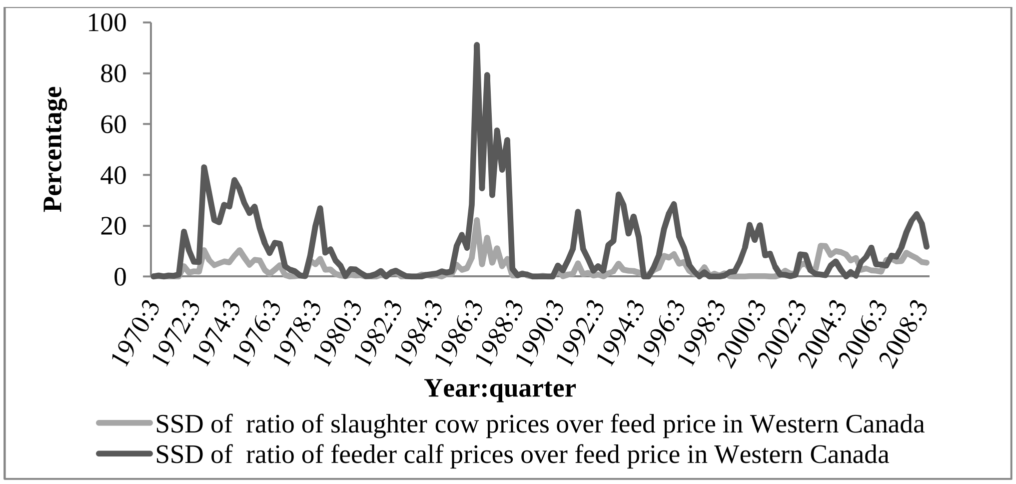
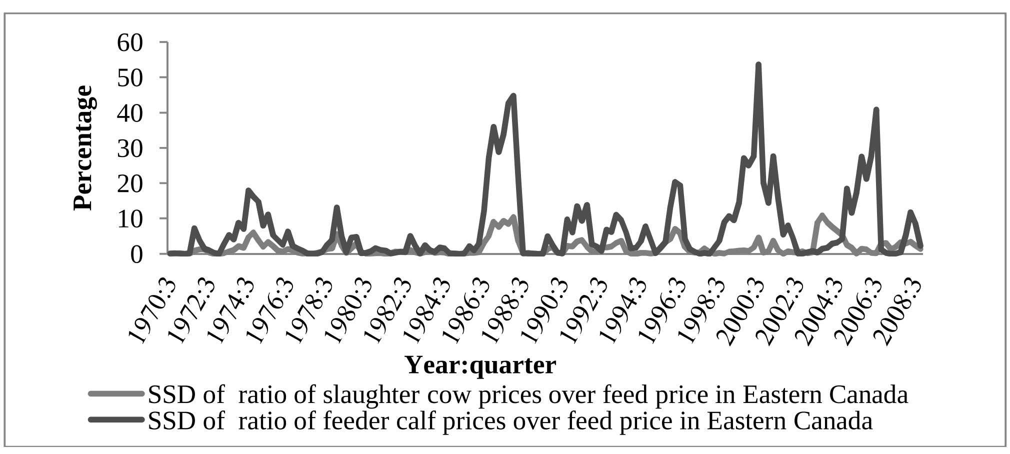


Figure 5.13 Squared Standard Deviations (SSDs) of Slaughter Cow and Feeder Calf Price Ratios in Eastern Canada



where BSE1 and BSE2 are, respectively, gross BSE information available for producers in Western Canada and Eastern Canada. GOVBSE1 and GOVBSE2 are, respectively, BSE information addressing government available for producers in Western Canada and Eastern Canada. SCIBSE1 and SCIBSE2 are, respectively, BSE information addressing scientists available for producers in Western Canada and Eastern Canada. FARBSE1 and FARBSE2 are, respectively, BSE information addressing producers available for producers in Western Canada and Eastern Canada.

The prices of slaughter cows and feeder calves are closely matched between Western Canada and Eastern Canada and in fact, without trade barriers, are determined in the North American market. The slaughter cow prices in Eastern Canada were mostly (85% of total observations) larger than that in Western Canada over history. The feeder calf prices in Western Canada were larger than in Eastern Canada during the period from 1997 to the middle of 2006. A large decline in prices of slaughter cows and feeder calves was seen in the second quarter of 2003, possibly due to lower slaughter cow demand after BSE related border closures. Although the prices of slaughter cows/bulls and feeder calves recovered after 2003, they were much lower than the pre-BSE levels. Feed grain prices in both Western Canada and Eastern Canada also suffered declines from 2003 but recovered in 2007. The SSD of price ratios showed that the variances or price risks associated with feeder calves are higher than those associated with slaughter cows. Producer subsidy estimates (OECD, 2009) were the highest in 2003 and 2004. Annual bank rates were fluctuating downwards, indicating that capital input prices were declining for cow-calf operations. In terms of BSE information indices, the number of BSE-related media articles matches the occurrences of BSE cases found in Canada. Specifically, the number of BSE messages increased in the second quarter of 2003, the first quarter of 2004 and the first quarter of 2005.

The descriptive and trend analyses above reveal the fact that the Western and Eastern Canadian beef industries have different scale and trends in cow-calf production and face different input and output prices as well as other factors.

These issues suggest the need for separate estimations of Western Canada and Eastern Canada instead of a whole Canadian model. Further, the BSE outbreak would have had a larger impact in cow-calf production in Western Canada than in Eastern Canada due to the scale of the industry. In the following sections, we will first report estimates of beef cow inventory and slaughter cow/bull supply equations, test for structural changes in these equations due to BSE and other factors, and then summarize the estimation results.

5.2.2 Beef Cow Inventory Model

A preliminary estimation of beef cow inventory equation 3.48 or 3.49 revealed a positive sign of feed grain prices in beef cow inventory which didn't make sense considering the rationality of cow-calf producers (they should decrease the beef cow numbers if the input cost rises). The lagged feed grain prices also had a positive parameter in beef cow inventory equation. Therefore, we modified the equation 3.48-3.49 by using the ratios between the slaughter cow prices and feed grain prices and the ratios between the feeder calf prices and feed grain prices as explanatory variables. Therefore, the prices of feeder calves and slaughter cows are normalized by feed grain prices.

The beef cow inventory equation (equation 3.50) specified in empirical model chapter is estimated using the annual time series data during the period 1940-2008 in Western Canada and Eastern Canada. To examine the impacts of BSE outbreak in Canada, the parametric structural break test[50] is first employed for Western Canada and Eastern Canada models to test whether slope parameters are the same before and after BSE outbreaks. The beef cow inventory models are then estimated and reported afterwards.

5.2.2.1 Parametric Structural Break Test

The structural break test applied for 2003 is a Chow test based on the beef cow inventory model (equation 3.50)[51]. The results of Chow tests for both Western

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[50] The non-parametric test for producers is based on either profit maximization or cost minimization. However, we don't have the complete dataset about the input quantities such as cow purchased, feed grain used or capital inputs. Therefore, the non-parametric test is not used.

[51] The historical events related with BSE such as the first case of BSE found in the end of 1993 and the claim of possible relationship between BSE and human vCJD in the beginning of 1996 are

Canada and Eastern Canada model suggest that there were no structural breaks in beef cow inventories due to BSE outbreaks in 2003 (P-value of Chow test is 0.64 for Western Canadian model and 0.11 for Eastern Canadian model). These results can be further confirmed by Figure 5.4. Although there were certain increases in beef cow inventory in Western Canada in 2004 and 2005, the historical trend for beef cow inventories in Western Canada is smooth without a sharp rise or decline around 2003. In Eastern Canada, the trend in beef cow inventories is even smoother than in Western Canada. Although there are no structural changes in beef cow inventories in Western Canada and Eastern Canada, there might be certain structural changes in provincial beef cow inventory, which will be examined using the models based on regionally-augmented panel data.

Other time periods are also tested for structural breaks and Chow test statistics suggest that there is a structural break in 1995 in Western Canada (P-value of Chow test is 0.04 for Western Canadian model), which is possibly due to the entrance of Canada into the WTO or the elimination of the Crow Rate.

5.2.2.2 Model Estimation

The beef cow inventory model is estimated based on equation 3.50. However, to improve the model fit, several likelihood ratio tests are applied to remove variables (e.g. interest rates, variances/ covariances of price ratios) with insignificant effects[52]. The time periods for the border closure and re-opening for Canadian beef and live cattle are also tested but are not significant and are removed based on likelihood ratio tests. The model is also tested for heteroskedasticity and autocorrelation. Because Lagrange multiplier tests and Durbin's H tests[53] suggested heteroskedasticity and auto-correlation in both Western Canadian and Eastern Canadian models, beef cow inventory equations

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also tested for structural changes. The results show they didn't cause any structural changes in beef cow inventories.

[52] The producer subsidy estimates should also be incorporated into the beef cow inventory equation as well. However, we only have data for producer subsidy estimates (PSE) starting from 1979. If we impute the missing observations by zero or by linear imputation, the estimation results showed an insignificant effect of PSE and the removal of PSE can actually increase the model fitness. Therefore, the PSE variable is not included in the beef cow inventory equation.

[53] Because the Durbin Watson test is not appropriate when the lagged dependent variables are incorporated in the model, we have to use Durbin'H test instead for autocorrelation test.

are estimated using an exact maximum likelihood method that is robust to these error structures. The results of the final reduced model (with the highest goodness of fit measures) are reported in Table 5.2.

Table 5.2 Estimation Results of Beef Cow Inventory Equations in Western Canada and Eastern Canada

Dependent variable	Beef cow inventory in Western Canada	Beef cow inventory in Eastern Canada
Parameter	Estimates[a]	Estimates
Constant	1610.620 (2.370) **	37.087 (1.760)
Feeder calf price/feed price[b]	310.926 (2.660) ***	49.002 (2.330) **
Cow price/feed price	-774.348 (-3.280) ***	-
Beef cow inventory lagged one period	0.578 (5.820) ***	0.884 (21.750) ***
Dummy for WTO (or Crow Rate)	186.654 (2.170) *	-
RHO	0.958 (33.250) ***	0.474 (3.990) ***
R-squared	0.995	0.978

a: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significance levels. “-“ represents the variables not significant and removed by likelihood ratio tests.
b: The variable ‘feeder calf price/feed price’ in Eastern Canada is lagged two periods due to the insignificance of current and lagged one period variables.

A BSE dummy for 2003 and dummies for each year after 2003 are also tried in both models but removed due to the insignificance, which makes sense considering the absence of structural breaks in 2003 and other years in the beef cow inventory equation. Dummies about significant changes in slaughter cow demand are also created and incorporated in the beef cow inventory equation. These dummies are set equal to one if cow slaughter is less than 20% of the annual monthly average in the 12 months before BSE, and zero otherwise. The initial model regression, however, failed to identify any significance of these dummies and therefore, they were removed to improve model fit. As shown in Table 5.2, Western Canada and Eastern Canada have different production structures. Specifically, in Eastern Canada, lagged beef cow inventory has a higher impact to the current beef cow inventory as compared with that in Western

Canada, implying the speed of adjustment of beef cow inventory in Eastern Canada is slower than that in Western Canada. The ratio of feeder calf price over feed price and the ratio of cow price over feed price play significant roles in beef cow inventory in Western Canada while in Eastern Canada, only the ratio of feeder calf price over feed price lagged two periods plays a significant role (97.5% significance) in beef cow inventory. These price ratios have the expected signs. Specifically, when the ratio of cow price over feed price increases, cow-calf producers want to sell their cows to enjoy increasing profit. On the other hand, when the ratio of feeder calf price over feed price increases, cow-calf producers may hold their cows to enjoy the future profits from the sale of feeder calves from cow breeding. The WTO dummy has a significantly positive impact on beef cow inventories in Western Canada, suggesting that the scale of cow-calf production in Western Canada has increased after Canada entered WTO or after the elimination of Crow Rate. However, beef cow inventories in Eastern Canada were not affected significantly by WTO entrance or the elimination of Crow Rate. The short run and long run price elasticities of beef cow inventories in Western Canada and Eastern Canada are calculated and presented in Table 5.3.

Table 5.3 Short Run and Long Run Price Elasticities of Beef Cow Inventories in Western Canada and Eastern Canada Evaluated by Sample Means

Parameter	Western Canada[b]	Eastern Canada
Short run feeder calf price elasticities[a]	0.093 (2.660) ***	0.060 (2.330) **
Short run cow price elasticities	-0.128 (-3.280) ***	-
Long run feeder calf price elasticities	0.220 (2.220) *	0.515 (2.340) **
Long run cow price elasticities	-0.304 (-2.730) ***	-

a: The elasticities of feeder calves (cows) are actually the elasticities of ratios of feeder calves (cows) over feed grain prices.
b: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels. “-“ represents the variables not significant and removed by likelihood ratio tests.

The elasticities of beef cow inventories with respect to feeder calf prices and cow prices provide certain measures for the impacts from different prices. For example, in Western Canada, a unit increase in slaughter cow price ratio over feed price will decrease beef cow inventory by approximately 0.13 units while a unit increase in feeder calf price ratio over feed price will raise beef cow inventory by approximately 0.09 units. Therefore, cow-calf producers in Western Canada are more sensitive to slaughter cow price changes and a same increase of the two prices will lead cow-calf producers to decrease their beef cow inventories. Eastern Canada has lower short-run and higher long-run feeder calf price elasticities as compared to those in Western Canada.

5.2.3 Slaughter Cow Supply Model with Predictive Difference Approach

5.2.3.1 Parametric Structural Break Test

The structural break test applied is a chow test based on equation 3.57[54]. The results of Chow tests suggest that there was a structural break in slaughter cow supplies in Western Canada due to the BSE outbreak in 2003 (Chow test statistic=3.6513, p-value=0.0001). However, slaughter cow supplies in Eastern Canada don't exhibit a structural break due to BSE (Chow test statistic=1.6752, p-value=0.108). Other time periods before and after 2003 are also tested and the results fail to identify any structural breaks.

The structural break tests are further confirmed by Figure 5.1 concerning slaughter cow supplies. Western Canada showed a sharp decline after the BSE outbreak in 2003 while Eastern Canada showed a much smaller decline. The predictive differences estimated in the following section will provide more information about the slaughter cow supply changes after the BSE outbreak in Canada.

5.2.3.2 Model Estimations

A preliminary model (equation 3.56) with the prices of slaughter cows, feeder calves and feed grains incorporated as explanatory variables failed to generate significant parameters for any of the prices. As well, parameter for feed grain prices was negative, which is not logical considering the fact that cow-calf

[54] The historical events related with BSE such as the first case of BSE found in the end of 1993 and the claim of possible relationship between BSE and human vCJD in the beginning of 1996 are also tested for structural changes. The results show they didn't cause any structural changes in slaughter cow supplies.

producers will cull more cows if their input costs increase. Therefore, we adopted the same procedure as in beef cow inventory equation by using the ratio between cow prices and feed grain prices and the ratio between feeder calf prices and feed grain prices as explanatory variables in slaughter cow supply equations.

The model (equation 3.57 and Figure 3.5) is estimated through ordinary least square method because no autocorrelation was detected. To improve the model goodness of fit, several likelihood ratio tests are applied to remove variables (such as interest rates, lagged producer subsidy estimates and covariances among prices) with insignificant effects. Adjustments for heteroskedasticity are made if necessary. The model also uses several other tests to test for insignificant variables and improve the goodness of fit of the model (e.g. R-squared, AIC or BIC). In the quarterly slaughter cow supply equations, the annual beef/dairy cow inventories are converted to quarterly data by assuming the inventory numbers of beef/dairy cows are the same for all four quarters of the same year [55]. The trade barriers due to BSE are incorporated into the model using dummies (Table 5.4) .

Table 5.4 Dummies for the Time Periods of Border Closure and Re-Opening from Other Countries to Canadian Beef and Live Cattle Related to BSE Outbreak and the Significant Changes of Slaughtering Demand

Year, quarter	Event	Variable and definitions
The second quarter, 2003	Border closures of the U.S. and all other countries for Canadian beef and live cattle.	Dbse=1 if t>the second quarter, 2003; 0 otherwise
The third quarter, 2003	Mexico opened its border to Canadian boneless bovine meat from cows under 30 months of age and boneless veal meat from cows nine months of age or younger	Liftmexbf=1 if t> the third quarter, 2003; 0 otherwise
The fourth quarter, 2003	Canadian boneless beef from animals younger than 30 months has been allowed into the United States under a permit process.	Liftusbf=1 if t> the fourth quarter, 2003; 0 otherwise
The fourth quarter, 2004	Hong Kong Cuba opened for Canadian beef	Lifthkbf=1 if t> the fourth quarter, 2004; 0 otherwise
The first quarter, 2005	Cuba Re-opened Border to Canadian cattle	Liftcusc=1 if t> the first quarter, 2005; 0 otherwise
The second quarter, 2005	Vietnam has opened to Canadian boneless beef under 30 month	Liftvnbf=1 if t> the second quarter, 2005; 0 otherwise

[55] Other methods of conversion are also tried including the linear interpolation and the use of January inventories of current year as the inventories of 3rd and 4th quarters of previous year the inventories of the 1st and 2nd quarter of current year. These two methods didn't show any improvement of model fitness or the significant levels of inventory variable in slaughter cow supply equations.

The third quarter, 2005	The U.S. border is open to Canadian cattle and bison less than 30 months of age ; New Zealand has opened to Canadian boneless beef	Liftussc=1 if t> the third quarter, 2005; 0 otherwise
The fourth quarter, 2005	Japan opened to Canadian beef	Liftjpbf=1 if t> the fourth quarter, 2005; 0 otherwise
The first quarter, 2006	Mexico expanded market access to Canadian beef	liftmexbf2=1 if t>the first quarter, 2006; 0 otherwise
The first quarter, 2007	Egypt opens border to Canadian breeding cattle	Liftegsc=1 if t>the first quarter, 2007; 0 otherwise
The second quarter, 2007	Taiwan lifts ban on Canadian beef imports	Lifttwbf=1 if t> the second quarter, 2007; 0 otherwise
The fourth quarter, 2007	U.S. border was open to all age Canadian cattle in November, 2007	Liftussc2=1 if t> the fourth quarter, 2007; 0 otherwise
The fourth quarter, 2008	Mexico reopened border to Alberta breeding cattle.	Liftmexsc=1 if t> the fourth quarter, 2008; 0 otherwise
The third quarter, 2003, the first and second quarters, 2005	Significant changes of slaughter cow demand in Alberta	ABSL=1 if cow slaughter is less than 20% of annual monthly average in 12 months before BSE; 0 otherwise
The second quarter, 2003, the fourth quarter, 2003-the fourth quarter, 2004	Significant changes of slaughter cow demand in B.C., Manitoba/Saskatchewan	BCSL=1 if cow slaughter is less than 20% of annual monthly average in 12 months before BSE; 0 otherwise

Source: data are from CFIA webpage.

These dummies are incorporated into the slaughter cow supply equation first and likelihood ratio tests are applied to remove the insignificant dummies and improve the model fit. Because there is a structural change in slaughter cow supply in Western Canada due to BSE, it is necessary to estimate a model before BSE outbreak for Western Canada. A slaughter cow supply model for Eastern Canada before BSE outbreak is also estimated. The model estimated over the entire period (the first quarter, 1972-the fourth quarter, 2008) has incorporated the interactions between the independent variables and the BSE dummy for the second quarter, 2003 to account for the structural change in the second quarter, 2003 (Greene, 2005). Some of these interaction terms are removed by likelihood ratio tests to improve model fit. Similar to the beef cow inventory equation, the dummies for significant changes in slaughter cow demand are also created and incorporated in the beef cow inventory equation. They were, however, insignificant and were, therefore, removed to improve model fit. The final version of the slaughter cow supply equations for Western Canada and Eastern Canada are reported in Table 5.5.

Table 5.5 Estimation Results of the Slaughter Cow Supply Equations for Western Canada and Eastern Canada Based on Time Series Data and Predictive Difference Approach

Dependent variable / Parameter	Slaughter cow supply in Western Canada, the first quarter, 1972-the fourth quarter, 2008	Slaughter cow supply in Western Canada, the first quarter, 1972- the first quarter, 2003	Slaughter cow supply in Eastern Canada, the first quarter, 1972- the fourth quarter, 2008	Slaughter cow supply in Eastern Canada, the first quarter, 1972- the first quarter, 2003
Constant	42.338 (2.011) *	53.878 (2.432) **	67.349 (5.211) ***	63.877 (4.012) ***
Feeder calf price/feed price	-45.314 (-3.057) ***	-34.851 (-1.732) #	-44.793 (-3.105) ***	-43.273 (-1.585)
Cow price/feed price	67.699 (2.018) *	43.942 (1.012)	11.149 (1.756) #	11.665 (0.85)
Squared standard deviation (SSD) of ratio of slaughter cow price over feed price[a]	112.278 (2.039) *	107.894 (1.34)	126.18 (3.365) ***	165.014 (2.112) *
SSD of ratio of feeder calf price over feed price	-24.715 (-1.897) #	-23.686 (-1.312)	-25.546 (-2.768) ***	-33.863 (-1.892) #
Slaughter cow supply lagged one period	0.444 (7.066) ***	0.523 (6.476) ***	0.682 (12.384) ***	0.692 (10.71) ***
Beef and dairy cow inventories lagged one period	0.012 (2.228) *	0.008 (1.414)	NA	NA
Dairy cow inventories lagged one period		NA	0.0001 (2.275) *	0.001 (1.782) #
Producer subsidy estimates	0.065 (0.733)	0.063 (0.708)	0.056 (1.059)	0.064 (0.978)
Time trend	0.203 (2.948) ***	0.171 (2.172) *	- [b]	-
Quarter 1	-32.385 (-9.051) ***	-38.626 (-9.06) ***	-14.003 (-6.162) ***	-15.176 (-5.587) ***
Quarter 2	-52.952 (-15.477) ***	-55.263 (-14.558) ***	-18.232 (-8.165) ***	-18.288 (-6.999) ***
Quarter 3	-44.034 (-13.547) ***	-44.031 (-12.081) ***	-21.937 (-10.317) ***	-22.313 (-8.479) ***
DBSE*	-0.443	-	-0.241	-

Producer subsidy estimates	(-5.078) ***		(-4.522) ***	
Liftussc	10.001 (1.74) #	-	-	-
Liftussc2	36.224 (4.145) ***	-	-	-
R-squared	0.859	0.816	0.747	0.680

a: SSD of ratio of feeder calf price (slaughter cow price) over feed price is lagged three periods due to the insignificance of current period variables.

b: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "-" represents the variables not significant and removed by likelihood ratio tests. "#" represents the variables with 90% significance. "NA" means "not available".

As shown in Table 5.5, all price ratios have the expected signs. For example, the ratio of feeder calf prices over feed grain prices, as an indicator of future benefits from calf breeding, has a negative impact on current slaughter cow supply. The ratio of cow prices over feed grain prices, as an indicator of current benefits from selling cows, has a positive impact on current slaughter cow supply. Seasonality is evident in both Western and Eastern Canadian models. The producer subsidies are not significant in either the Western Canada or Eastern Canada models, based on the entire period. However, the interaction term between the BSE dummy and producer subsidy estimates is significantly negative in both the Western Canada and Eastern Canada models based on the entire period, implying that the government support for cow-calf producers has reduced extra slaughter cow supplies in both Western and Eastern Canada. The parameter on the lagged dependent variable of slaughter cow supply in Western Canadian model is less than that in Eastern Canadian model, suggesting that the speed of adjustment of slaughter cow supply toward long run equilibrium in Western Canada is faster than that in Eastern Canada. The parameter for beef and dairy cow inventories lagged one period in Western Canada is significantly positive, suggesting that an increase in cattle inventories can increase the slaughter cow supplies in Western Canada. In Eastern Canada, the dairy cow inventories play a significantly positive role in slaughter cow supplies, which makes sense considering that a large number of slaughter cattle are from dairy herds (estimated

68% of cows come from the dairy sector in Eastern Canada in 2008) in Eastern Canada[56].

The squared standard deviation (SSD) of price ratios represents the effects of price risks on the slaughter cow supply equation. The SSDs of price ratios play significant roles in slaughter cow supplies in both Western Canada and Eastern Canada based on the entire period. Further, SSDs of different prices play different roles in slaughter cow supply in Western Canada, which may reflect the risk preferences of cow-calf producers in Western Canada. For example, cow-calf producers may prefer a risk from feeder calf prices to enjoy possible profit in the future by decreasing cow supply and increasing number of cows for breeding. In contrast, cow-calf farmers may avoid the price risk from slaughter cows by increasing slaughter cow supplies in the current period.

The re-opening of borders from the U.S. for Canadian live cattle has had a positive impact in Western Canadian slaughter cow supply. However, such an impact is not significant at the third quarter, 2005 (U.S. border was open to Canadian cattle and bison less than 30 months of age). It is the fourth quarter, 2007 (U.S. border was open to Canadian cattle at all ages) for which a significant change in Western Canadian slaughter cow supplies was identified. For Eastern Canada, the border closure and re-opening didn't play a significant role in slaughter cow supplies.

Comparing the results from different periods in Western/Eastern Canadian models, slaughter cow price ratio was less significant before the BSE outbreak in 2003, implying that cow prices play a more crucial role post BSE. The parameter of the feeder calf price ratio becomes more negative in the entire period as compared to the pre-BSE period, suggesting slaughter cow supplies are more volatile in response to the feeder calf price ratio after the BSE outbreak. The SSDs of prices play significant roles in slaughter cow supplies in Western/

56 According to the "2008 - Statistics of the Canadian Dairy Industry - Complete publication" from Canadian Dairy Information Centre, the culling rate of dairy cows in 2008 is 23%. The dairy cows culled in Eastern Canada in 2008 are therefore computed by: dairy cows culled in Eastern Canada in 2008=dairy cow inventory in Eastern Canada in 2008*23%. The percentage of slaughter cow supplies from dairy industry in Eastern Canada in 2008 is estimated by: dairy cows culled in Eastern Canada in 2008/slaughter cow supply in Eastern Canada in 2008.

Eastern Canada based on the entire period but are mostly not significant based on period before BSE outbreak, suggesting that cow-calf producers in Western/ Eastern Canada are affected significantly by price variations after the BSE outbreak. The short run and long run price elasticities are reported in Table 5.6.

Table 5.6 Short Run and Long Run Price Elasticities of Slaughter Cow Supplies in Western Canada and Eastern Canada Based on Time Series Data and Predictive Difference Approach Evaluated by Sample Means

Region and period / Parameter[a]	Western Canada		Eastern Canada	
	The first quarter, 1972- the fourth quarter, 2008	The first quarter, 1972-the first quarter, 2003	The first quarter, 1972- the fourth quarter, 2008	The first quarter, 1972-the first quarter, 2003
Short run elasticities of feeder calf prices[b]	-0.398 (-3.057) ***	-0.31 (-1.732) #	-0.232 (-3.105) ***	-0.231 (-1.585)
Short run elasticities of cow prices	0.29 (2.018) *	0.204 (1.012)	0.113 (1.756) #	0.112 (0.85)
Long run elasticities of feeder calf prices	-0.716 (-3.538) ***	-0.649 (-1.938) #	-0.731 (-2.671) ***	-0.751 (-1.451)
Long run elasticities of cow prices	0.522 (2.208) *	0.428 (1.082)	0.355 (1.643)	0.363 (0.815)
Short run elasticities of variances of feeder calf prices	-0.027 (-1.897) #	-0.027 (-1.312)	-0.024 (-2.768) ***	-0.029 (-1.892) #
Short run elasticities of variances of cow prices	0.035 (2.039) *	0.027 (1.34)	0.029 (3.365) ***	0.031 (2.112) *
Long run elasticities of variances of feeder calf prices	-0.048 (-1.867) #	-0.056 (-1.355)	-0.075 (-2.668) ***	-0.095 (-1.87) #
Long run elasticities of variances of cow prices	0.063 (2.004) *	0.058 (1.394)	0.09 (3.034) ***	0.1 (2.033) *
Short run elasticities of beef and dairy cow inventories[c]	0.42 (2.228) *	0.269 (1.414)	0.002 (0.026)	0.009 (1.782) #
Long run elasticities of beef and dairy cow inventories	0.754 (2.396) **	0.564 (1.548)	0.005 (0.026)	0.03 (1.711) #
Short run elasticities of producer subsidy estimates	0.021 (0.733) post-BSE period: -0.31 (-6.26) ***	0.014 (0.708)	0.023 (1.059) post-BSE period: -0.234 (-4.185) ***	0.019 (0.978)

Long run elasticities of producer subsidy estimates	0.037 (0.742) post-BSE period: -0.556 (-5.686) ***	0.03 (0.715)	0.072 (1.037) post-BSE period: -0.737 (-3.961) ***	0.06 (0.956)

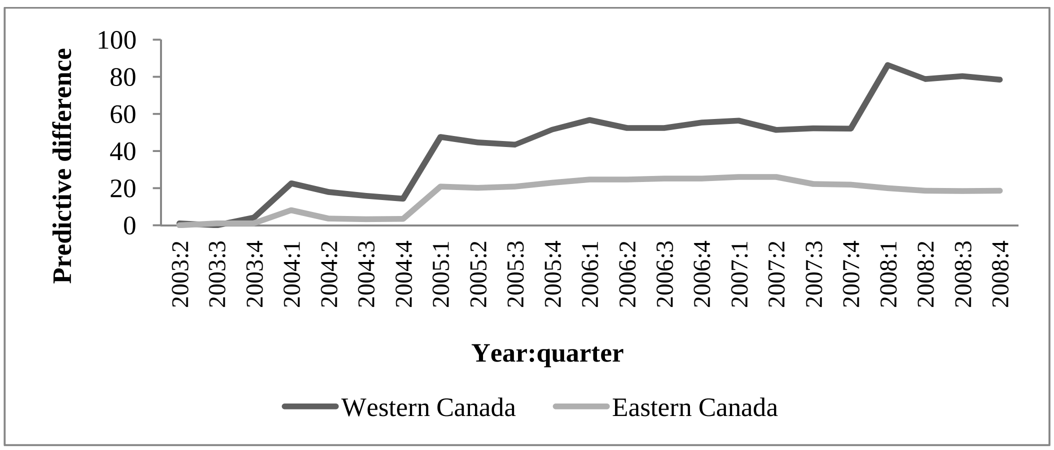
a: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents the variables with 90% significance.
b: The elasticities of feeder calves (cows) are actually the elasticities of ratios of feeder calves (cows) over feed grain prices.
c: The elasticities of beef and dairy cow inventories in Eastern Canada are for dairy cow inventories.

Both short run and long run elasticities of feeder calf prices are negative while short run and long run elasticities of cow prices are positive. The absolute value of the short run feeder calf price elasticity is larger in Western Canada as compared with that in Eastern Canada, possibly due to the fact that cow supply in Eastern Canada is mostly from the dairy industry, which is less dependent on feeder calf prices than that in Western Canada. On the other hand, the absolute value of slaughter cow price elasticity is larger in Western Canada as compared with that in Eastern Canada. The elasticities of price variances show similar signs as compared to the elasticities of prices. For example, if the price variances of slaughter cows increase, cow-calf producers may believe it is too risky to hold cows over a long time, and decide to sell them. The elasticities of cow supplies with respect to beef and dairy cow inventories are positive in Western Canada and Eastern Canada, suggesting that more slaughter cows will be provided by a larger cattle herd.

The elasticities of cow supplies with respect to producer subsidy estimates are insignificantly positive before the BSE outbreak but are significantly negative after the BSE outbreak, suggesting that cow-calf producers may hold their cattle longer given government support such as cattle Set-Aside programs or risk reduction program after BSE outbreak. As far as model results from different periods are concerned, the absolute values of feeder calf price elasticity and cow price elasticity in the Western Canadian model are larger based on whole period as compared with those based on pre-BSE period, implying that slaughter cow supplies of cow-calf producers in Western Canada are more sensitive to feeder calf price and cow price changes after BSE outbreak.

As discussed previously, the predictive difference approach involves estimations and predictions over the period before BSE outbreaks ($\hat{Y}_t$) and over the entire period ($\hat{\hat{Y}}_t$). The predictive difference ($Pd_{f,t}$) is evaluated by the differences between two predictions for the period after BSE outbreak ($Pd_{f,t} = \hat{\hat{Y}}_t - \hat{Y}_t$) (Figure 5.14). The predictive differences for slaughter cow supplies in Western Canada and Eastern Canada are positive during the period from the second quarter of 2003 to the fourth quarter of 2008, which suggests that a model estimated up until just before May 2003 would have predicted smaller slaughter levels than what is predicted by a model based on the entire period. In Eastern Canada, the predictive differences are smaller suggesting perhaps a smaller impact of BSE on the slaughter decision.

Figure 5.14 Predictive Differences Based on Time Series Data of Slaughter Cow Supplies



The predictive differences are used as independent variables in equation (3.70) and the estimated risk perception equations are reported in Table 5.7. In Western Canada and Eastern Canada, both the gross media index and the subject media indices about BSE have significant impacts on BSE risk perceptions of cow-calf producers. Therefore, SARF is supported by estimates of behaviour in the cow-calf industry in both Western Canada and Eastern Canada. Lagged risk perceptions don’t play a significant role in the risk perception models for Western Canada. A time trend has a significantly positive impact on BSE risk perceptions in Western and Eastern Canada, implying that risk perceptions of cow-calf producers may be increasing over time.

The elasticities of risk perceptions with respect to different information indices about BSE are reported in Table 5.8. The table shows a negative elasticity of gross BSE information and a positive elasticity of BSE information addressing government in both Western and Eastern Canadian cow-calf producers, implying that BSE information about government amplifies while the gross BSE information attenuates cow-calf producers' risk perceptions. The gross BSE information focusing on scientists has a negative elasticity in Western Canada but a positive elasticity in Eastern Canada, suggesting that scientific information about BSE may have enlarged risk perceptions for Eastern Canadian farmers but decreased risk perceptions for Western Canadian farmers. However, such impacts are negligible due to the statistical insignificance of gross BSE information focusing on scientists in risk perception equations for both Western and Eastern Canada.

Table 5.7 Results from BSE Risk Perception Equation Based on Time Series Data of Slaughter Cow Supplies and Predictive Difference Approach, The Second Quarter, 2003-The Fourth Quarter, 2008

Dependent variable: risk perception deviations approximated through predictive difference approach		
Independent variables	Parameter Estimates[a]	
	Western Canada	Eastern Canada
Constant	-64.921 (-7.95) ***	-26.761 (-5.409) ***
Gross BSE information lagged one period	-2.027 (-2.102) #	-1.64 (-2.291) *
BSE information addressing government lagged one period	2.129 (3.038) ***	1.606 (2.623) **
BSE information addressing scientists lagged one period	-0.428 (-0.978)	0.01 (0.035)
Risk perception lagged one period	0.052 (0.359)	0.447 (2.303) *
Time trend	3.47 (7.658) ***	1.009 (3.566) ***
Log likelihood	-78.516	-69.077
Schwarz B.I.C.	87.922	78.483

a: All BSE information indices are of 100 messages. BSE information indices are all lagged one period due to the insignificant of their current values in model.
b: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents the variables with 90% significance.

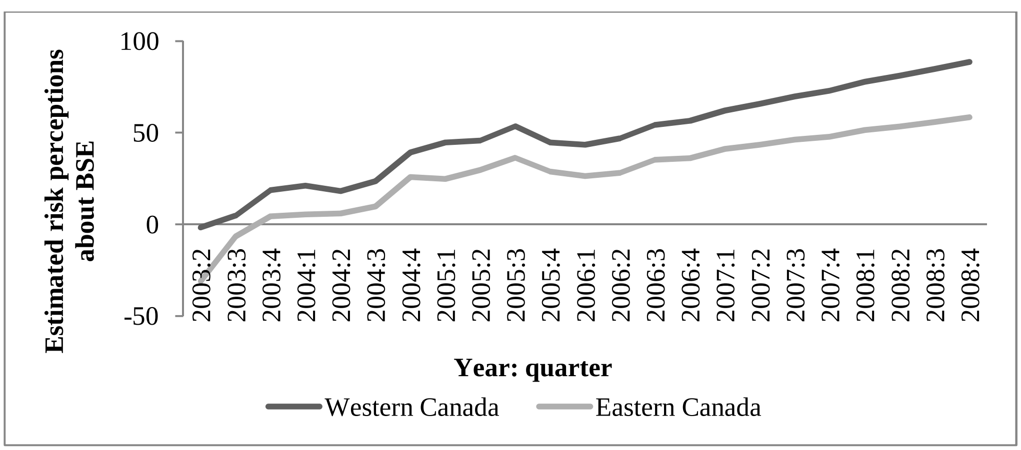
Table 5.8 Elasticities of Cow-Calf Farmer Risk Perceptions with respect to Different Information Indices, The Second Quarter, 2003-The Fourth Quarter, 2008

Elasticities[a]		Western Canada	Eastern Canada
Short run	Gross BSE information lagged one period	-0.282 (-2.102) *	-0.188 (-2.291) **
	BSE information addressing government lagged one period	0.370 (3.038) ***	0.253 (2.623) ***
	BSE information addressing scientists lagged one period	-0.050 (-0.978)	0.001 (0.035)
Long run	Gross BSE information lagged one period	-0.298 (-2.315) **	-0.339 (-1.865) #
	BSE information addressing government lagged one period	0.391 (2.934) ***	0.456 (1.688) #
	BSE information addressing scientists lagged one period	-0.053 (-0.97)	0.002 (0.035)

a: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents the variables with 90% significance.

The time trend of risk perceptions held by cow-calf producers is illustrated in Figure 5.15. The graph shows increasing risk perceptions related to BSE for cow-calf producers in both Western and Eastern Canada, suggesting that cow-calf producers feel that their industry is more risky after BSE-related market adjustments. Further, Western Canadian cow-calf producers felt more risk than Eastern Canadian cow-calf producers.

Figure 5.15 Risk Perceptions of BSE (RPBSE) Based on Time Series Data of Slaughter Cow Supplies and Predictive Difference Approach



5.2.4 Slaughter Cow Supply Model with State-Space Approach

The results of slaughter cow supply equations based on state-space approach (Figure 3.7) are reported in Table 5.9. Similar to the results for the predictive difference approach, the price ratios all have expected signs in the state-space model of slaughter cow supply. The quarterly dummies have significant impacts in cow supplies in Western Canada but not in Eastern Canada. However, the variables for price risks are not playing significant roles in cow supply decisions. The risk perception of BSE has a significant positive impact on slaughter cow supply in Western Canada, implying producers in Western Canada tend to sell their cows facing BSE risk. The parameters of the gross media information about BSE and BSE information addressing government are significant in Western Canada, suggesting SARF. In Eastern Canada, the gross media information about BSE also has a significant positive impact on risk perceptions about BSE. The number of significant parameters based on the state-space approach is less than that based on predictive difference approach, which may be reasonable considering the complexity of the state-space model and that the complexity may lead to some high correlation among parameters. However, the parameters associated with risk perceptions can be evaluated through the state-space model and therefore, the elasticities of slaughter cow supply with respect to risk perceptions of BSE can be measured.

Table 5.9 Estimation Results of the Slaughter Cow Supply Equations for Western Canada and Eastern Canada Based on Time Series Data and State-Space Approach, The First Quarter, 1972-The Fourth Quarter, 2008

Parameter[a]	Estimates	
	Western Canada	Eastern Canada
Constant	14.320 (6.590) ***	-0.022 (0.010)
Feeder calf price/feed price	-19.180 (-7.410) ***	-0.461 (-1.750) #
Cow price/feed price	29.550 (6.270) ***	0.341 (1.756) #
Squared standard deviation of ratio of slaughter cow price over feed price	12.870 (1.530)	14.270 (1.260)
Squared standard deviation of ratio of Feeder calf price over feed price	-4.508 (-1.730)	-5.104 (-1.027)
Slaughter cow supply lagged one period	0.793	0.504

	(4.220) ***	(1.740) #
Beef and dairy cow inventories lagged one period[b]	0.008 (1.720)	0.001 (0.320)
Producer subsidy estimates	-0.028 (-0.110)	-
Time trend	0.122 (0.510)	-
Quarter 1	6.869 (5.040) ***	0.010 (0.010)
Quarter 2	4.216 (3.480) ***	-0.069 (-0.010)
Quarter 3	-0.375 (-0.370)	-0.133 (-0.010)
Liftussc	4.276 (0.981)	-
Liftussc2	5.173 (4.265) ***	-
Liftmexsc	4.125 (1.312)	-
Parameter of risk perceptions about BSE	0.014 (4.040) *	0.018 (0.003)
Gross BSE information lagged one period	-2.978 (-3.600) *	-0.340 (2.660) *
BSE information addressing government lagged one period	0.033 (-2.010) *	-
BSE information addressing scientists lagged one period	-3.021 (0.810)	-
DIC(Deviation Information Criteria)	-1000.500	-959.000

a: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents variables with 90% significance level. "-" represents variables not significant and removed by likelihood ratio tests.
b: In Eastern Canada, only dairy cow inventories are included.

The price and risk perception elasticities are reported in Table 5.10. In the same way as in the predictive difference approach, the long run price elasticities are larger than short run ones and have expected signs. The short-run elasticity of slaughter cow price is larger in Eastern Canada as compared with that in Western Canada. In the long run, the reverse is true. The elasticities of feeder calf prices are larger in Eastern Canada than those in Western Canada. This is a little different from the results of the predictive difference approach where the Western Canada model always had higher feeder calf price elasticities than the Eastern Canada model in the short run. These differences might be due to the fact that model specifications from the predictive difference approach and the state-space approach are different. However, the results from predictive different approach might be more reliable considering the fact that cow-calf operations are of a larger scale in Western Canada as compared to that in Eastern Canada and cow-calf producers in Western Canada should be more sensitive to feeder calf prices than those in Eastern Canada.

The rise in price variances of slaughter cows leads to an increase of in the number of cows sold from producers probably due to the larger uncertainty in cow-calf operations. However, the rise of price variances of feeder calves leads to the decrease of cows sold from producers, suggesting that cow-calf producers may prefer the price risks from feeder calves and increase the number of breeding cows to enjoy the possible profits from price variations. The cow-calf producers, therefore, might be characterized as risk-averse in cow prices but risk-prefer in feeder calf prices. Producer subsidy estimates have a positive impact on slaughter cow supply, implying the government programs for alleviating extra slaughter burden were effective. These results are the same as the elasticity estimates from the predictive difference approach. Further, the elasticities of risk perceptions about BSE are all positive in Western Canada and Eastern Canada but only the one in Western Canada is significant, implying that BSE risk perceptions push producers to sell more of cows.

Table 5.10 Short (Long) Run Elasticities of Prices and Risk perceptions in Slaughter Cow Supplies of Western Canada and Eastern Canada Based on Time Series Data and State-Space Approach Evaluated by Sample Means

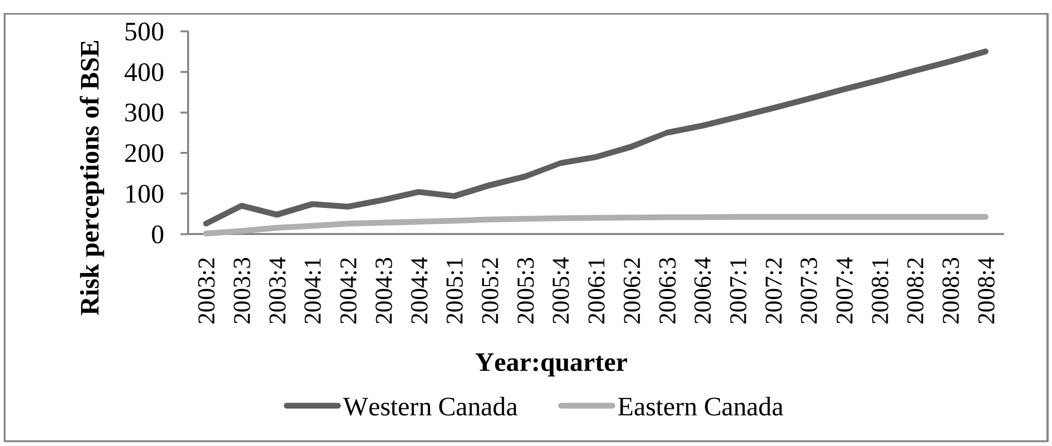
Parameter[a]	Western Canada	Eastern Canada
Long run elasticities of cow prices	0.633 (6.050) ***	0.401 (1.654) #
Short run elasticities of cow prices	0.128 (6.270) ***	0.199 (1.320)
Long run elasticities of feeder calf prices	-0.843 (-7.130) ***	-1.057 (-0.750)
Short run elasticities of feeder calf prices	-0.170 (-7.410) ***	-0.524 (-1.330)
Long run elasticities of producer subsidy estimates	-0.075 (-2.420) **	-
Short run elasticities of producer subsidy estimates	-0.018 (-0.110)	-

Long run elasticities of variances of cow prices	0.020 (1.530)	0.011 (0.781)
Short run elasticities of variances of cow prices	0.004 (1.530)	0.005 (0.650)
Long run elasticities of variances of feeder calf prices	-0.024 (-1.760) #	0.009 (1.054)
Short run elasticities of variances of feeder calf prices	-0.005 (-1.730) #	0.005 (1.248)
Short run elasticities of beef and dairy cow inventories	0.038 (1.731)	0.019 (0.245)
Long run elasticities of beef and dairy cow inventories	0.732 (1.812)	0.082 (0.236)
Long run elasticities of risk perceptions about BSE	0.011 (3.050) **	0.015 (0.020)
Short run elasticities of risk perceptions about BSE	0.002 (2.620) *	0.003 (0.010)

a: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels. “#” represents variables with 90% significance. “-“ represents variables not significant and removed by likelihood ratio tests.

The estimated risk perception is plotted (Figure 5.16). The trend in risk perceptions associated with BSE is quite similar to that based on the predictive difference approach, suggesting an increasing risk perception in Western Canada and Eastern Canada. Both the predictive difference approach and the state-space approach based on the time series data of Western/Eastern Canada assumed that the regional data within Western/Eastern Canada can be pooled. A regional analysis would be preferable if the poolability is rejected. Therefore, we also need to examine whether the beef cow inventory and slaughter cow supply models disaggregated into sub-regions show the same response patterns.

Figure 5.16 Risk Perceptions of BSE (RPBSE) Based on Time Series Data of Slaughter Cow Supplies and State-Space Approach



5.3 Cow-Calf Farmer Model Based on Regionally Disaggregated Panel Data

5.3.1 Regionally Disaggregated Panel Data

The provinces in Western and Eastern Canada are disaggregated into four regions. Region 1 represents Alberta, region 2 represents B.C., Saskatchewan and Manitoba, region 3 represents Ontario, and region 4 represents Quebec and the Maritime Provinces. The regional disaggregation is based on the fact that the numbers of slaughter cows in B.C., Saskatchewan and Manitoba were merged starting in January, 2000 and the fact that the numbers of slaughter cows in Quebec and Maritime Provinces were merged starting in April, 2001. The slaughter cow supplies in a region are computed as the sum of the number of slaughter cows in that region plus the net import of slaughter cows in that region. The descriptive analyses for the variables applied in the panel data model are reported in Table 5.11.

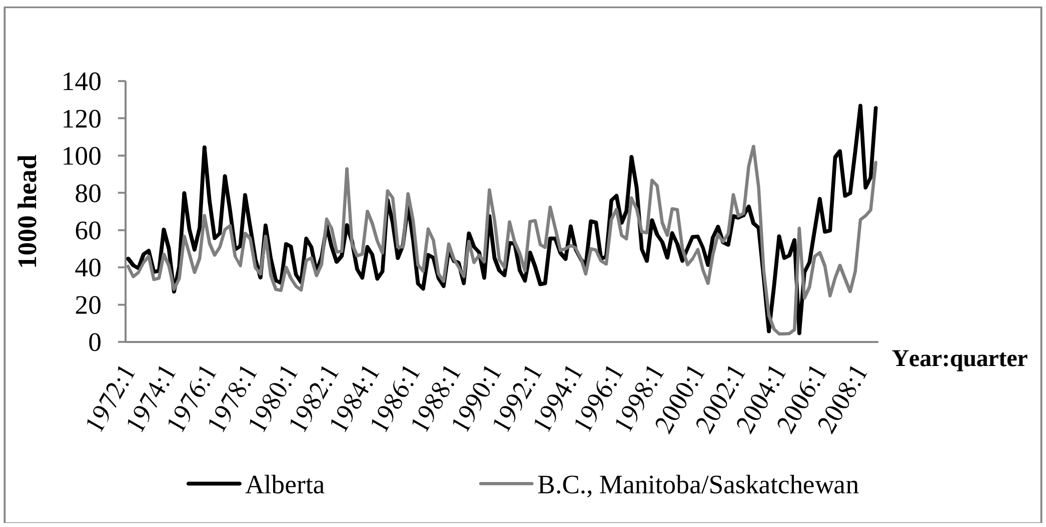
Table 5.11 Descriptive Analysis of Quarterly Panel Data by Region, 1970-2008

Region / Stat. / Variables	Alberta			B.C./Manitoba/Saskatchewan			Ontario			Quebec/Atlantic provinces		
	Mean (std. error)	Min	Max	Mean (std. error)	Min	Max	Mean (std. error)	Min	Max	Mean (std. error)	Min	Max
Slaughter cow supply[a]	53.940 (19.200)	4.680	126.770	50.050 (18.100)	4.240	104.980	32.180 (9.640)	2.800	53.230	48.410 (9.420)	25.300	72.400
Beef cow inventory	1192.700 (560.800)	215.000	2090.000	1318.300 (631.900)	188.400	2518.000	330.890 (121.200)	77.000	540.000	175.930 (93.600)	18.800	310.700
Dairy cow inventory	193.600 (90.700)	79.500	369.900	371.660 (228.500)	143.000	887.300	710.430 (277.600)	320.000	1135.000	883.300 (292.500)	419.800	1293.400
Producer subsidy ($ per metric tonne)	81.710 (62.500)	4.250	294.250	81.710 (62.500)	4.250	294.250	81.710 (62.500)	4.250	294.250	81.710 (62.500)	4.250	294.250
Price of feeder calves ($/100 lbs)	61.770 (45.520)	5.640	163.240	61.770 (45.520)	5.640	163.240	53.600 (43.700)	2.900	154.310	53.600 (43.700)	2.900	154.310
Price of slaughter cows ($/100 lbs)	39.180 (16.890)	13.230	69.210	39.180 (16.890)	13.230	69.210	41.060 (17.550)	13.660	74.550	41.060 (17.550)	13.660	74.550
Price of feed grain ($ per metric tonne)	59.330 (46.800)	6.000	238.590	59.330 (46.800)	6.000	238.590	70.060 (44.740)	16.000	252.050	70.060 (44.740)	16.000	252.050
Bank rate (percentage)	5.370 (3.590)	1.500	17.930	5.370 (3.590)	1.500	17.930	5.370 (3.590)	1.500	17.930	5.370 (3.590)	1.500	17.930
Gross BSE information	77.000 (173.000)	0	800.000	77.000 (173.000)	0	800.000	61.000 (145.000)	0	768.000	61.000 (145.000)	0	768.000
Producer BSE information addressing government	16.000 (38.000)	0	152.000	16.000 (38.000)	0	152.000	16.000 (38.000)	0	152.000	16.000 (38.000)	0	152.000
Producer BSE information addressing scientists	2.000 (5.000)	0	26.000	2.000 (5.000)	0	26.000	2.000 (4.000)	0	25.000	2.000 (4.000)	0	25.000
Producer BSE information addressing producers	5.000 (13.000)	0	58.000	5.000 (13.000)	0	58.000	4.000 (9.000)	0	40.000	4.000 (9.000)	0	40.000

a: cow inventories are of 1000 heads. The producer subsidy estimates are only available for whole Canada and therefore, are assumed to be equal across different regions.

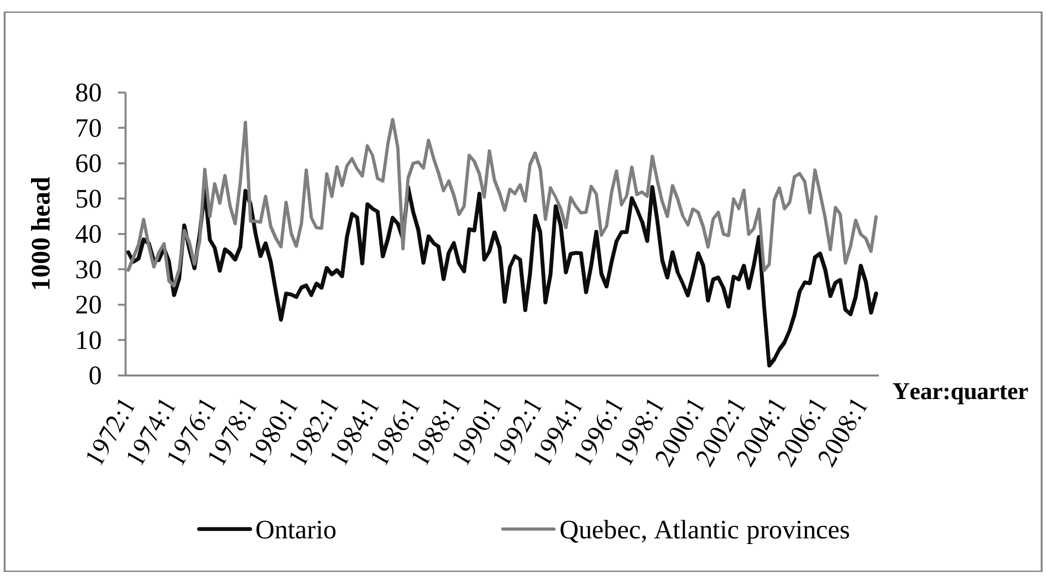
In terms of different provinces, Alberta has the highest quarterly average in slaughter cow supply and high averages of annual beef cow inventory. Ontario, on the other hand, has the highest average number of dairy cows. The producer subsidy estimates, interest rates, BSE information and prices of feeder calves, slaughter cows and feed grain are the same across the regions in Western and Eastern Canada. The trends in quarterly slaughter cow supplies and exports by region are illustrated by Figure 5.17 to 5.22.

Figure 5.17 Quarterly Slaughter Cow Supply (Including Domestic Slaughtering and Export) by Regions in Western Canada, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

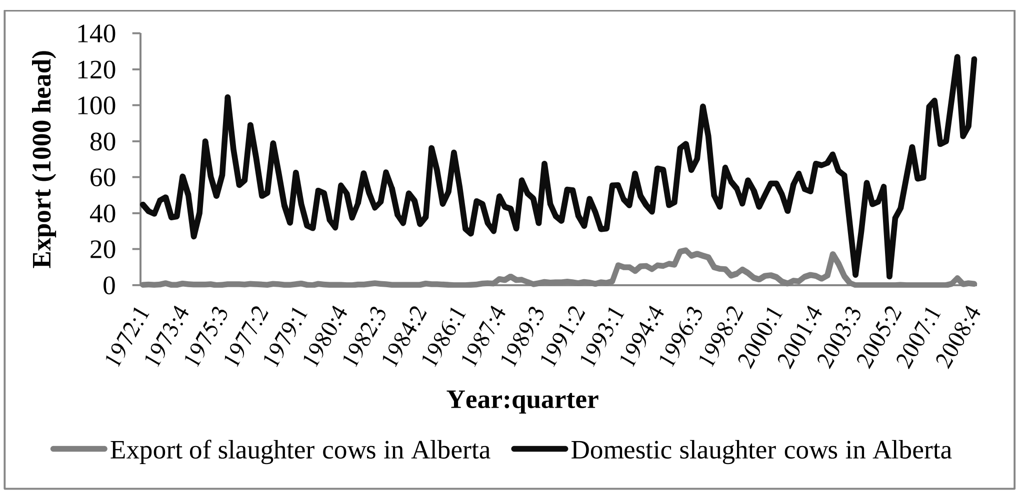
Figure 5.18 Quarterly Slaughter Cow Supply (Including Domestic Slaughtering and Export) by Regions in Eastern Canada, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

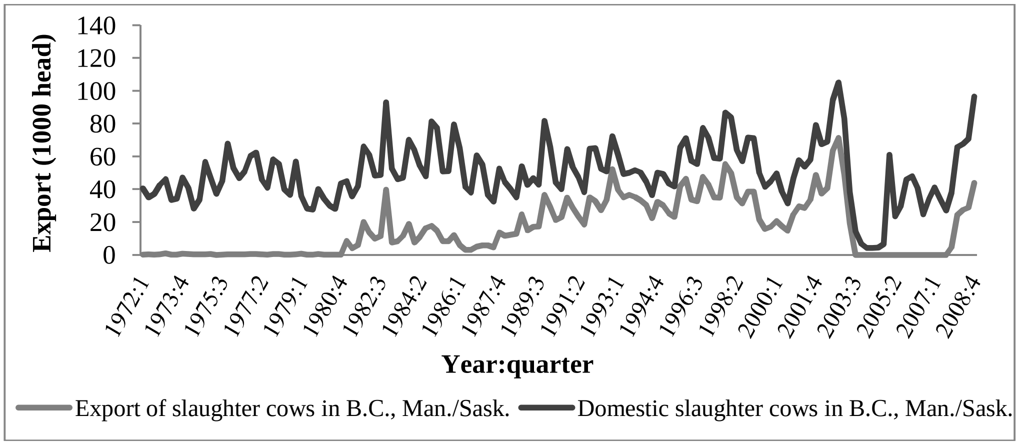
The number of slaughter cows supplied in the second quarter of 2003 shows a sharp decline in all regions. In the post-BSE period (after the second quarter of 2003), different regions seem to have had different responses in slaughter cow supply. For example, Alberta had a recovery in slaughter cow supply in 2004 but had another sharp decline in the first quarter of 2005, probably due to the two mad cow cases found in that province. After that, the slaughter cow supply in Alberta started to increase rapidly. In contrast, B.C./Manitoba/Saskatchewan had a low slaughter cow supply during 2004 but recovered in the first quarter of 2005 and declined afterwards. In the short term, the low levels of slaughter cow supply might also be a result of government policies designed to reduce the extra cattle supply in the Canadian domestic market and relieve the slaughter burden. The slaughter cow supply in Eastern Canada seems not to have been affected much by the BSE outbreak. The slaughter cow supply in Ontario, Quebec/Atlantic provinces increased between 2003 and 2006 and declined afterwards. Interestingly, in the third quarter of 2003 when three BSE-infected cows were found, B.C./Manitoba/Saskatchewan, Ontario, Quebec/Atlantic provinces all had a decline in their slaughter cow supplies. To understand the slaughter cow supplies in different regions, slaughter cow exports and domestic cows for slaughtering are graphed as follows:

Figure 5.19 Quarterly Numbers of Cows Slaughtered and Exported in Alberta, 1972-2008



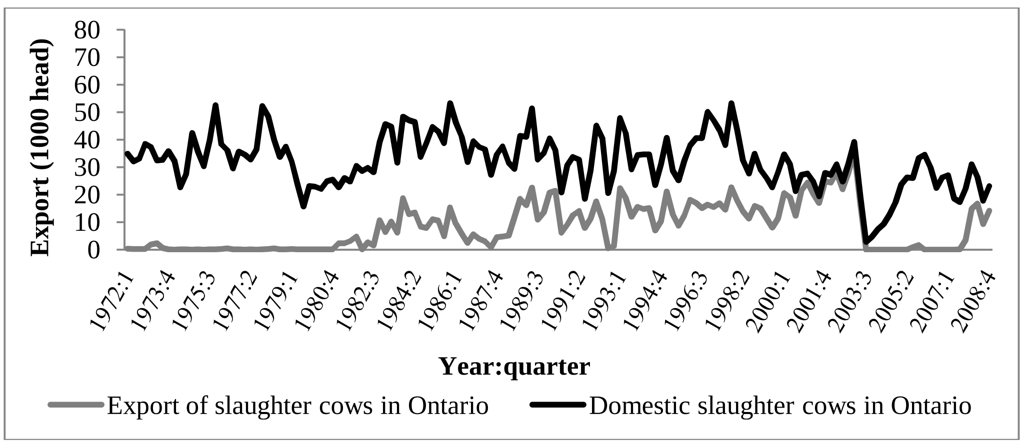
Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

Figure 5.20 Quarterly Numbers of Cows Slaughtered and Exported in B.C./ Manitoba/Saskatchewan, 1972-2008



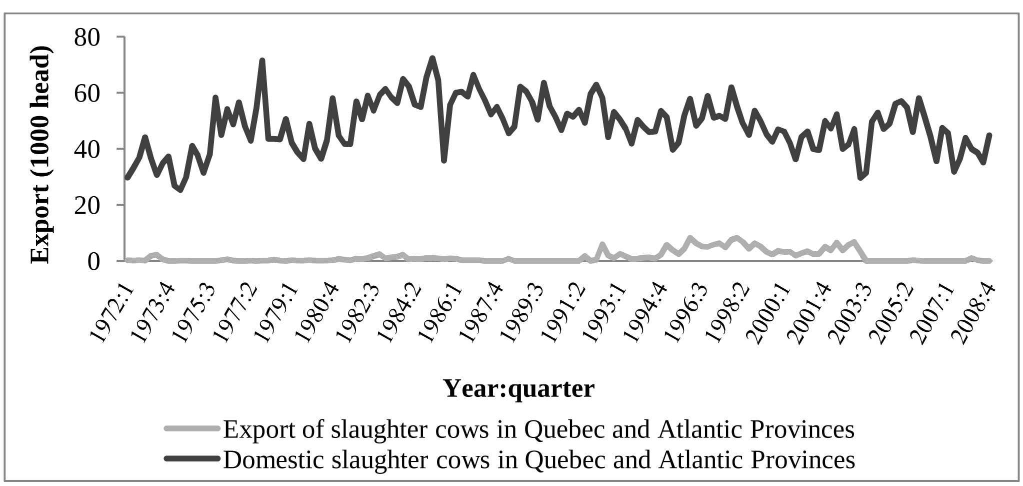
Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

Figure 5.21 Quarterly Numbers of Cows Slaughtered and Exported in Ontario, 1972-2008



Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

Figure 5.22 Quarterly Numbers of Cows Slaughtered and Exported in Quebec/Atlantic provinces, 1972-2008

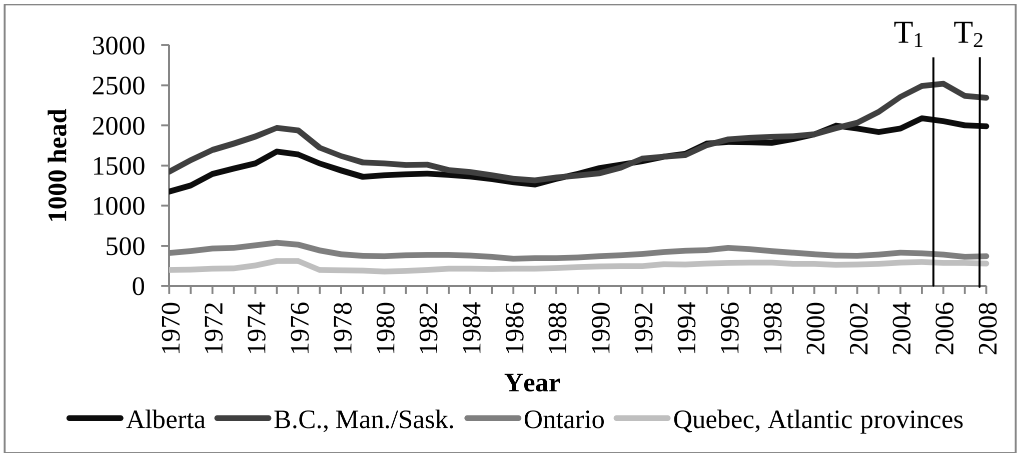


Data come from the Livestock and Meat Trade Report of AAFC 1972-1999 and CANFAX 2000-2008.

The exports and domestic slaughtering of cows have a positive relationship in Alberta, B.C./Manitoba/Saskatchewan (correlation coefficient=0.22 for Alberta and 0.71 for B.C./Manitoba/Saskatchewan)(Figure 5.19 and 5.20). This positive relationship might be due to the expansion of cow-calf operations in Western Canada. Domestic slaughter number of cows in Alberta had two sharp declines (in the second quarter, 2003 and the first quarter, 2005) and increased afterwards. Between the two sharp declines (the second quarter, 2003-the first quarter, 2005), there was a big recovery in slaughter cow supplies in Alberta. The domestic slaughter number of cows in B.C./Manitoba/Saskatchewan had two declines at the same time as Alberta and increased afterwards. But there was little recovery of slaughter cow supplies in B.C./Manitoba/Saskatchewan between the two declines. The increase of domestic slaughter numbers of cows suggested an expanded slaughtering capacity at post-BSE periods. The export of slaughter cows was fluctuating in B.C./Manitoba/Saskatchewan (upwards) and Alberta but disappeared from the second quarter, 2003 to the third quarter, 2007 due to border closures from other countries. After 2007, the export of slaughter cows increased rapidly in B.C./Manitoba/Saskatchewan as compared to Alberta.

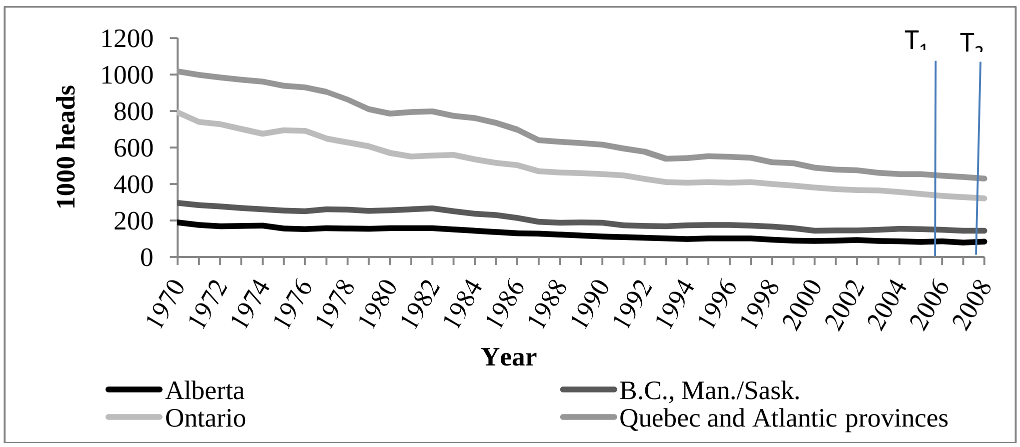
The domestic slaughter numbers of cows in Ontario and Quebec/Atlantic provinces showed certain declines in the second quarter, 2003 but rebounded afterwards (Figure 5.21 and 5.22). The slaughter numbers of cows in the two regions is fluctuating downwards over history. The exports of slaughter cows were fluctuating in Ontario (upwards) and Quebec as well as Atlantic provinces but stopped from the second quarter, 2003 to the third quarter, 2007 due to border closures from other countries. After 2007, the export of slaughter cows increased rapidly in Ontario as compared with Quebec/Atlantic provinces. Slaughter cow supplies may be affected by the beef and dairy cow inventories, which are reported in Figures 5.23 and 5.24.

Figure 5.23 Annual Beef Cow Inventory by Region, 1970-2008



Data come from the Statistics Canada database CANSIM II Table 30032. T_1 is the time when U.S. border was open to Canadian live cattle under 30 months old in July, 2005. T_2 is the time when U.S. border was open to all age Canadian cattle in November, 2007.

Figure 5.24 Annual Dairy Cow Inventory by Region, 1970-2008



Data come from the Statistics Canada database CANSIM II Table 30032. T_1 is the time when U.S. border was open to Canadian live cattle under 30 months old in July, 2005. T_2 is the time when U.S. border was open to all age Canadian cattle in November, 2007.

The beef cow inventories in all regions reached high levels in 1975. From 1975 to 1986, all regions had declines in beef cow inventory. After 1986, the beef cow inventory in Alberta, B.C./Manitoba/Saskatchewan increased rapidly. The beef cow inventory in Alberta reached a peak in 2005 and that in B.C./Manitoba/Saskatchewan reached a peak in 2006 and declined afterwards. These declines might be the joint results of slaughter capacity expansion and the border opening from other countries to Canadian cows, which have been illustrated in Figure 5.23. Ontario, Quebec/Atlantic provinces didn't show as much variation in beef cow inventories as compared to Alberta and B.C./Manitoba/Saskatchewan, probably due to the fact that Eastern Canada has a higher percentage of dairy cows instead of beef cow operations. The dairy cow inventories are much higher in regions of Eastern Canada as compared to those in Western Canada. In all regions, the dairy cow inventories are declining over time and there are no sharp changes in dairy cow inventories in 2003, 2005 (U.S. border was open to Canadian live cattle under 30 months old) or 2007 (U.S. border was open to all age Canadian cattle).

The descriptive analyses for the regionally disaggregated panel data show that there are different patterns in slaughter cow supplies across regions, which demands a regional analysis in terms of beef cow inventory and slaughter cow supply equations. Also, we found larger fluctuations of slaughter cow supplies in regions in Western Canada as compared with regions in Eastern Canada. To determine the impacts of the BSE outbreak in Canada, a structural break test is employed in the following sections for beef cow inventory and slaughter cow supply equations.

5.3.2 Beef Cow Inventory Model

The beef cow inventory equation (equation 3.51) specified in model construction section is estimated using the regionally disaggregated panel data for the period 1940-2008. The structural break test[57] is first employed to check if the BSE outbreak has caused any structural changes in regional beef cow inventories.

5.3.2.1 Parametric Structural Break Test

The structural break tests are applied to the beef cow inventory equation for each region and all four regions together. Specially, a predictive Chow test is applied to test a structural break due to the BSE outbreak in 2003[58] due to insufficient observations after 2003 to estimate the beef cow inventory equations. The test results suggest that there were no structural changes due to BSE in any regions except B.C./Manitoba/Saskatchewan. The beef cow inventory in B.C./Manitoba/

[57] The non-parametric test for producers is based on either profit maximization or cost minimization. However, we don't have the complete dataset about the input quantities such as cow purchased, feed grain used or capital inputs. Therefore, non-parametric test is not used.

[58] The historical events related with BSE such as the first case of BSE found in the end of 1993 and the claim of possible relationship between BSE and human vCJD in the beginning of 1996 are also tested for structural changes. The results show they didn't cause any structural changes in beef cow inventories.

Saskatchewan seemed to be significantly affected by BSE outbreak (Chow test=2.36, p-value=0.04). This is further supported by checking the historical trend of beef cow inventories in B.C./Manitoba/Saskatchewan (Figure 4.18). The beef cow inventory in B.C./Manitoba/Saskatchewan did show a larger fluctuation as compared to other regions. However, compared with the sharp changes in slaughter cow supplies (Figure 4.15), the changes in beef cow inventories were very small. The estimation results of beef cow inventory equations are reported in the following section.

5.3.2.2 Model Estimation

The beef cow inventory equation is estimated by region and by the pooled panel data for all regions. Before estimating the pooled panel data model, a poolability test is employed to check if the regional data can be pooled together (Baltagi, 2001). The poolability test result suggests that the regional data are poolable (F statistic=1.440, p-value=0.07) and therefore, panel data estimation is justified. Further, the beef cow inventory equations by region and for the panel data from all regions are corrected for first order autocorrelation of error terms. To improve the model fit, several likelihood ratio tests are applied to remove variables (e.g. interest rates, variances and covariances of price ratios, producer subsidy estimates) with insignificant effects. The dummies for the trade barriers due to BSE and the significant changes of slaughtering demand are also included in the initial model but are not significant and are removed by likelihood ratio tests.

The results of final model estimations are reported in Table 5.12. Because in most regions, there are no structural breaks in the beef cow inventory due to BSE, it is not necessary to report the model estimations during the pre-BSE period before 2003. In the beef cow inventory equations for Alberta, B.C./Manitoba/ Saskatchewan, the dummy for WTO or elimination of Crow Rate is significant while in other regions, it is not. The ratio of feeder calf price over feed grain price and the ratio of cow price over feed grain price show the expected signs in beef cow inventories. The regionally specific intercepts (ID1-ID4) are all significantly positive and different in the panel data model, which may be due to different regional policy arrangements and other regional specific factors that support expansion of cow-calf production. The lagged beef cow inventory is significant in each regional model and the panel data model.

Table 5.12 Estimation Results of Beef Cow Inventory Equations by Regional Model and Panel Data Model

Parameter	Estimates				
	Panel data (fixed effect)	Alberta	B.C./Manitoba /Saskatchewan	Ontario	Quebec/Atlantic Provinces
ID1[a]	100.124 (4.350) ***	1148.360 (2.540) **	-	-	-
ID2	111.069 (4.540) ***	-	669.858 (1.980) *	-	-
ID3	37.547 (2.560) **	-	-	34.378 (1.730)	-
ID4	29.263 (2.100) *	-	-	-	4.295 (0.680)
Feeder calf price/feed price	76.640 (2.940) ***	128.782 (2.120) *	167.964 (2.360) **	21.921 (1.880)	33.005 (2.800) ***
Cow price/feed price	-182.444 (-3.370) ***	-365.785 (-3.020) ***	-385.461 (-2.630) ***	-	-
Beef cow inventory lagged one period	0.953 (64.710) ***	0.432 (4.130) ***	0.634 (5.550) ***	0.871 (15.910) ***	0.880 (22.350) ***
Dummy for WTO	-	85.986 (1.940) *	103.572 (1.970) *	-	-
RHO	0.578 (10.790) ***	0.970 (48.400) ***	0.942 (20.570) ***	0.622 (5.300) ***	0.149 (1.170)
R-squared	0.997	0.994	0.994	0.981	0.962
Hausman test of specification of fixed effect v.s. random effect: Chi-squared test statistics= 8.734, P-value = 0.013					

a: ID1-ID4 represent the regional dummies with D1: Alberta, D2: B.C./Man./Sask., D3:Ontario, D4: Quebec/Atlantic Provinces.
b: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "-" represents variables not significant and removed by likelihood ratio tests.

The price elasticities are estimated and reported in Table 5.13. Regionally, the short run and long run feeder calf price elasticities in Quebec/Atlantic provinces are larger than those in Alberta, B.C./Manitoba/Saskatchewan or Ontario, suggesting that cow-calf producers in Quebec/Atlantic provinces might be more sensitive to changes in feeder calf prices. The short run cow price elasticities in Alberta and B.C./Manitoba/Saskatchewan are very similar in magnitude while in the long run, the cow price elasticity in B.C./Manitoba/Saskatchewan is larger than that in Alberta, implying that in the long run, cow-calf producers in B.C./Manitoba/Saskatchewan are more sensitive to cow price changes.

Table 5.13 Short Run and Long Run Price Elasticities of Beef Cow Inventories by Regional Model and Panel Data Model Evaluated by Sample Means

Elasticities	Estimates[b]				
	Panel data	Alberta	B.C., Man. /Sask.	Ontario	Quebec, Atlantic Provinces
Short run elasticity of feeder calf price[a]	0.070 (2.940) ***	0.081 (2.120) *	0.095 (2.360) **	0.041 (1.880) *	0.116 (2.800) ***
Short run elasticity of cow price	-0.094 (-3.370) ***	-0.128 (-3.020) ***	-0.122 (-2.630) ***	-	-
Long run elasticity of feeder calf price	1.484 (3.090) ***	0.142 (1.880) *	0.260 (1.950) *	0.317 (1.620) *	0.966 (3.630) ***
Long run elasticity of cow price	-1.991 (-3.190) ***	-0.225 (-2.570) **	-0.333 (-2.290) **	-	-

a: The elasticities of feeder calf (cow) prices are in fact the elasticities of ratio of feeder calf (cow) prices over feed grain prices. The elasticities of feeder calf prices in Ontario, Quebec, Atlantic Provinces are the elasticities of feeder calf prices lagged two periods.
b: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "-" represents variables not significant and removed by likelihood ratio tests.

5.3.3 Slaughter Cow Supply Model with Predictive Difference Approach

5.3.3.1 Parametric Structural Break Test

The Chow-type structural break test is applied for panel data and the result suggests a significant structural break occurred during the BSE outbreak in Canada[59] (Wald test statistic: 167.5654, p-value: 0.00001). The structural break test in the time series model of cow supplies has revealed a BSE-led structural break in Western Canada but not in Eastern Canada. Therefore, we can conclude that the structural break in panel data model from BSE outbreak is mainly caused by behavioural changes of Western Canada cow-calf producers. Other time periods are also tested and no structural changes are identified.

[59] The historical events related with BSE such as the first case of BSE found in the end of 1993 and the claim of possible relationship between BSE and human vCJD in the beginning of 1996 are also tested for structural changes. The results show they didn't cause any structural changes in slaughter cow supplies.

5.3.3.2 Model Estimation

Similar to the specifications in time series model, the slaughter cow supply model (equation 3.58) is estimated over the period before BSE outbreak in Canada ($\hat{Y}_t$) and the entire period ($\hat{\hat{Y}}_t$). The two models are used to generate two predictions after the BSE outbreak and the differences in these two predictions ($Pd_{f,t} = \hat{\hat{Y}}_t - \hat{Y}_t$) are used as proxies for deviations of BSE risk perceptions from baseline risk. Different from the time series model, the panel data model needs to be tested for poolability to make certain the regional data about slaughter cows supplies can be pooled together. A F-test is applied and the result rejects data pooling (F statistic= 6.7184, p-value=0.001). Therefore, the four regions are not poolable and the slaughter cow supply equation and risk perception equation is estimated by region. Some likelihood ratio tests are applied to remove insignificant variables and improve the model fit. The final model results are reported in Table 5.14.

For all regions, feeder calf price ratios have a significant impact (higher than 90% significance) on slaughter cow supplies with a negative parameter, as expected. Further, the parameter on feeder calf price ratios in Alberta model is more negative based on the entire period as compared to the period before BSE outbreak, implying that slaughter cow supplies in Alberta become more volatile with respect to feeder calf price after BSE. In contrast, B.C./Manitoba/ Saskatchewan and Ontario didn't show higher elasticities of slaughter cow supplies with respect to feeder calf prices. The slaughter cow price ratios have a significant positive parameter in all regions during the entire period, suggesting that cow-calf producers prefer the immediate profit from price increases of cull cows. The SSD of cow price ratios has a significant positive impact over slaughter cow supply, which makes sense considering that cow-calf producers will sell more cows when the risks associated with cow prices increase. The slaughter cow supply lagged one period has a significant impact on current slaughter cow supply but the impacts are regionally specific. The lagged slaughter cow supply plays a more important role in Eastern Canada regions as compared to Western Canada regions.

Table 5.14 Estimation Results for the Slaughter Cow Supply Equations Based on Panel Data

Regions	Alberta		B.C./Manitoba/Saskatchewan		Ontario		Quebec/Atlantic provinces	
Time period / Variables	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1
Constant	-1.229 (-0.082)	20.462 (1.522)	33.627 (2.475) **	28.94 (2.205) *	27.791 (4.33) ***	26.182 (3.244) ***	36.13 (4.132) ***	32.896 (3.297) ***
Feeder calf price/feed price	-29.688 (-3.132) ***	-9.41 (-1.962) *	-14.679 (-1.49)	-23.161 (-1.904) #	-22.599 (-2.733) ***	-28.893 (-1.882) #	-18.711 (-2.078) *	-4.585 (-2.253) *
Cow price/feed price	47.875 (2.142) *	6.153 (0.276)	18.143 (0.796)	34.492 (1.300)	5.097 (2.401) **	8.28 (1.986) #	4.917 (2.231) *	-0.983 (-2.115) *
Squared standard deviation (SSD) of ratio of slaughter cow price over feed price[a]	70.516 (1.843) #	64.894 (1.408)	77.363 (2.074) *	36.636 (0.722)	65.97 (3.048) ***	98.145 (2.199) *	55.704 (2.328) **	58.858 (1.238)
SSD of ratio of feeder calf price over feed price	-6.924 (-0.782)	-8.556 (-0.844)	-23.72 (-2.673) ***	-12.952 (-1.115)	-12.909 (-2.449) **	-21.416 (-2.089) *	-11.741 (-1.99) *	-11.247 (-1.036)
Slaughter cow supply lagged one period	0.27 (3.613) ***	0.497 (6.221) ***	0.491 (8.014) ***	0.581 (7.227) ***	0.659 (11.644) ***	0.643 (9.594) ***	0.698 (11.946) ***	0.702 (10.405) ***
Beef and dairy cow inventories lagged one period	0.034 (4.108) ***	0.016 (2.101) *	0.002 (0.421)	0.003 (0.568)	NA	NA	NA	NA
Dairy cow inventories lagged one period	NA	NA	NA	NA	0.001 (2.134) *	0.006 (0.781)	0.003 (1.903) *	0.004 (1.356)
Producer subsidy estimates	0.085 (0.954)	0.048 (0.608)	0.081 (0.659)	0.069 (0.605)	0.024 (0.391)	0.074 (0.959)	0.091 (1.377)	0.071 (0.894)
Time	-b	-	0.12 (2.637) ***	0.131 (2.638) **	-	-	-	-
Quarter 1	-14.079 (-5.574) ***	-19.155 (-7.727) ***	-14.952 (-6.829) ***	-19.888 (-8.394) ***	-3.619 (-2.883) ***	-4.103 (-2.693) ***	-10.473 (-7.354) ***	-11.089 (-6.835) ***
Quarter 2	-26.534	-27.907	-24.343	-27.619	-7.129	-7.276	-11.117	-10.947

	(-11.143) ***	(-12.525) ***	(-10.679) ***	(-11.967) ***	(-5.502) ***	(-4.752) ***	(-8.211) ***	(-7.069) ***
Quarter 3	-23.26 (-10.289) ***	-22.096 (-10.467) ***	-20.679 (-9.165) ***	-21.844 (-9.702) ***	-10.963 (-8.856) ***	-11.194 (-7.33) ***	-10.992 (-8.343) ***	-11.216 (-7.013) ***
DBSE*Producer subsidy estimates	-0.242 (-2.401) **	-	-0.463 (-3.121) ***	-	-0.283 (-4.597) ***	-	-0.191 (-2.885) ***	-
Liftussc[c]	18.817 (4.556) ***	-	-7.869 (-1.633)	-	5.715 (0.254)	-	1.545 (0.07)	-
Liftussc2	12.8 (2.167) *	-	25.371 (4.2) ***	-	11.453 (0.799)	-	11.63 (0.264)	-
ABSL	-19.629 (-3.168) ***	-	-	-	-	-	-	-
BCSL	-	-	-12.274 (-1.92) *	-	-	-	-	-
R-squared	0.816	0.772	0.804	0.78	0.755	0.636	0.688	0.666

a:SSD is the squared standard deviations of price ratios lagged three periods, used to approximate the effects of price variations.

b: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels. “#” represents variables with 90% significance level. “NA” means “not available”. “-“ represents variables not significant and removed by likelihood ratio tests.

c: liftussc, lftussc2, ABSL and BCSL are dummies for trade barriers lifting and the significant changes in slaughter cow demand, as defined in table 5.4.

The beef and dairy cow inventories lagged one period also have significant impacts in regions in Western Canada, suggesting that a large number of cow herds will provide more cows for slaughtering. Similar results are obtained for the dairy cow inventories in regions in Eastern Canada. The producer subsidy estimate (PSE) has an insignificant impact on slaughter cow supplies but its interactions with the BSE dummy has a significant negative impact on slaughter cow supplies in all regions, suggesting that government support has reduced the extra cow supplies in market after BSE outbreak in Canada. The quarterly dummies have significant impacts on cow supplies and the impacts varies between Alberta and B.C./Manitoba/Saskatchewan. The time trend has a significantly positive impact on slaughter cow supplies in B.C./Manitoba/ Saskatchewan, suggesting gradual structural changes in cow-calf production in these regions as shown by the expansion of cow-calf operations over time. The dummies for the lifting of trade barriers of live cattle from the U.S.(Lifeussc, Liftussc2) have a positive impact in slaughter cow supplies. Such an impact is significant for the Alberta model at the re-opening of US border in the third quarter, 2005 (The U.S. border opened to Canadian cattle and bison less than 30 months of age), and is significant for the B.C./Manitoba/Saskatchewan model in the fourth quarter, 2007 (U.S. border was open to all age Canadian cattle). The significant changes in slaughter demand in Alberta (ABSL) and B.C./Manitoba/ Saskatchewan (BCSL) have had a negative impact on slaughter cow supplies in these regions. To further analyze the impacts of price variables, the short run and long run price elasticities of cow supplies are reported in Table 5.15.

Table 5.15 Short Run and Long Run Price Elasticities of Slaughter Cow Supplies by Panel Data Evaluated by Regional Sample Means

Region	Alberta		B.C., Manitoba/ Saskatchewan		Ontario		Quebec, Atlantic provinces	
Time period / Variables	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1	1972:1-2008:4	1972:1-2003:1
Short run elasticities of feeder calf prices	-0.503 (-3.132) ***	-0.159 (-1.962) *	-0.268 (-1.49)	-0.423 (-1.904) #	-0.294 (-2.733) ***	-0.375 (-1.882) #	-0.162 (-2.078) *	-0.04 (-2.253) *
Short run elasticities of cow prices	0.396 (2.142) *	0.051 (0.276)	0.162 (0.796)	0.307 (1.300)	0.129 (2.401) **	0.21 (1.986) *	0.083 (2.231) *	0.017 (2.115) *
Long run	-0.689	-0.317	-0.526	-1.01	-0.861	-1.052	-0.535	-0.133

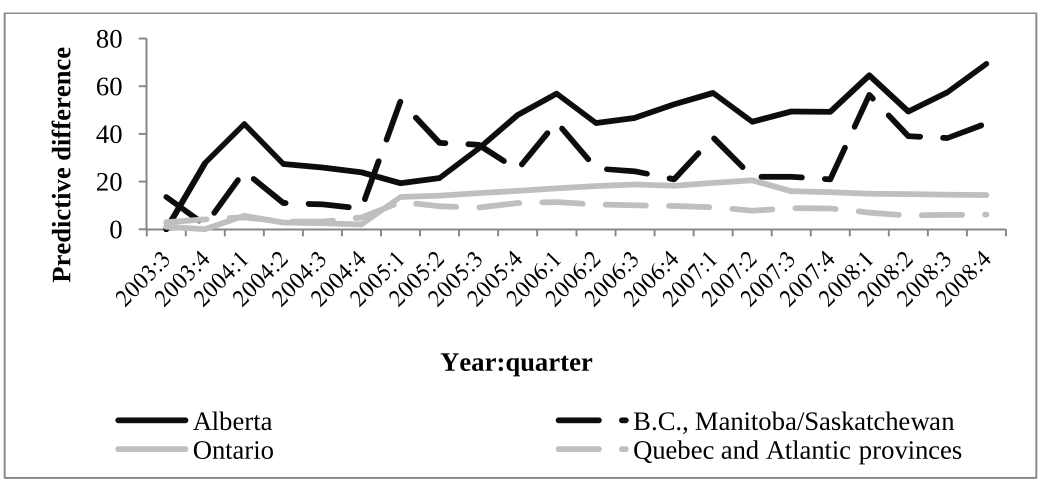
elasticities of feeder calf prices	(-3.504) ***	(-3.011) **	(-1.581)	(-2.097) *	(-2.405) **	(-1.752) #	(-1.904) #	(-2.269) **
Long run elasticities of cow prices	0.542 (2.292) **	0.101 (0.28)	0.317 (0.821)	0.734 (1.398)	0.379 (2.325) **	0.589 (2.047) *	0.275 (2.192) *	0.056 (2.196) *
Short run elasticities of Producer subsidy estimates	0.026 (0.954) post-BSE period -0.1 (-1.976) *	0.015 (0.608)	0.027 (0.659) post-BSE period -0.44 (-2.932) ***	0.023 (0.605)	0.012 (0.391) post-BSE period -0.515 (-5.062) ***	0.038 (0.959)	0.031 (1.377) post-BSE period -0.092 (-1.861) #	0.024 (0.894)
Long run elasticities of Producer subsidy estimates	0.036 (0.961) post-BSE period -0.137 (-1.943) #	0.029 (0.608)	0.053 (0.673) post-BSE period -0.863 (-2.686) ***	0.054 (0.624)	0.036 (0.391) post-BSE period -1.51 (-4.465) ***	0.106 (0.951)	0.103 (1.322) post-BSE period -0.305 (-1.881) #	0.082 (0.873)
Short run elasticities of variances of feeder calf prices	-0.014 (-0.782)	-0.018 (-0.844)	-0.053 (-2.673) ***	-0.029 (-1.115)	-0.03 (-2.449) **	-0.05 (-2.089) *	-0.018 (-1.99) *	-0.017 (-1.036)
Short run elasticities of variances of cow prices	0.043 (1.843) #	0.039 (1.408)	0.051 (2.074) *	0.024 (0.722)	0.038 (3.048) ***	0.056 (2.199) *	0.021 (2.328) **	0.022 (1.238)
Long run elasticities of variances of feeder calf prices	-0.02 (-0.78)	-0.035 (-0.847)	-0.104 (-2.623) ***	-0.069 (-1.178)	-0.088 (-2.274) **	-0.140 (-2.066) *	-0.060 (-2.03) *	-0.058 (-1.034)
Long run elasticities of variances of cow prices	0.059 (1.842) #	0.078 (1.425)	0.099 (2.025) *	0.057 (0.749)	0.11 (2.641) ***	0.157 (2.144) *	0.07 (2.315) **	0.075 (1.211)
Short run elasticities of beef and dairy cow inventories	1.094 (4.108) ***	0.509 (2.101) *	0.094 (0.421)	0.117 (0.568)	0.167 (2.134) *	0.186 (0.781)	0.036 (1.903) *	0.06 (1.356)
Long run elasticities of beef and dairy cow inventories	1.499 (4.735) ***	1.013 (2.445) **	0.185 (0.425)	0.279 (0.584)	0.49 (2.078) *	0.522 (1.021)	0.12 (1.914) *	0.2 (1.686)

a: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents variables with 90% significance.

Because the structural break test suggests that there is a structural break due to BSE in Western Canadian regions, we have to estimate the short run and long run price elasticities of slaughter cow supplies before the BSE outbreak. The short run and long run feeder calf price and cow price elasticities are much larger in Alberta as compared to other regions. The elasticities of producer subsidy estimates are significantly negative during the post-BSE period, implying that cow-calf producers saved their cows from market under the government assistance programs such as the Cattle Set-Aside programs. The elasticities of variance of slaughter cow prices are significantly positive (higher than 90% significance) in all regions based on the entire period, suggesting the slaughter cow price risks have pushed cow-calf producers to sell more of their cows. The elasticities of slaughter cow supplies with respect to feeder calf prices are negative, implying that cow-calf producers prefer some price risks from feeder calves and increase the number of cows for breeding. The elasticities of slaughter cow supplies with respect to beef and dairy cow inventories are positive in all regions, suggesting that herd size expansion can contribute more slaughter cow supplies. Comparing the two different periods, the feeder calf price and cow price elasticities in Alberta, Quebec/Atlantic provinces are larger after the BSE outbreak, implying that cow-calf producers are more sensitive to feeder calf/cow prices than before BSE.

The slaughter cow supply equation based on regional data is regressed over two periods: one is for the pre-BSE period (the first prediction) and the other is for the whole period (the second prediction). The predictive differences are estimated as the second prediction minus the first prediction. The predictive differences are plotted in Figure 5.25.

Figure 5.25 Predictive Differences Based on Slaughter Cow Supply Equations and Panel Data



The graph above shows that all regions except Quebec/Atlantic provinces have increasing predictive differences. Specifically, Western regions (e.g. Alberta, B.C./Manitoba/Saskatchewan) have higher fluctuations than the Eastern regions (e.g. Ontario, Quebec/Atlantic provinces). The estimations of risk perception equations are reported in Table 5.16.

Table 5.16 Results from BSE Risk Perception Equation Based on Panel Data of Slaughter Cow Supplies and Predictive Difference Approach

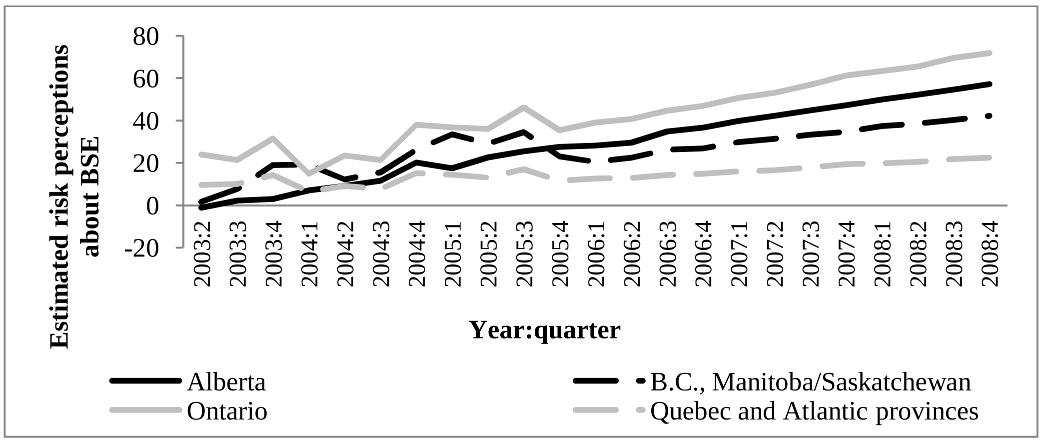
Dependent variables: risk perception deviations approximated by predictive different approach				
Variable	Estimates[a]			
	Alberta	B.C./Manitoba/Saskatchewan	Ontario	Quebec/Atlan.provinces
Constant	-18.105 (-2.3) *	-43.497 (-5.456) ***	-16.394 (-4.947) ***	-8.314 (-3.89) ***
Risk perception lagged one period	0.232 (0.916)	0.207 (1.045)	0.548 (2.926) ***	0.436 (2.049) #
Gross BSE information lagged one period	-0.406 (-0.445)	-1.713 (-1.712)	-1.13 (-2.48) **	-0.571 (-1.708)
BSE information addressing government lagged one period	0.414 (0.531)	2.025 (2.65) **	1.09 (2.706) **	0.628 (2.397) *
BSE information addressing scientists lagged one period	-0.333 (-0.711)	-0.223 (-0.506)	0.007 (0.035)	-0.012 (-0.088)
Time trend	1.466 (3.036) ***	1.889 (4.408) ***	0.641 (3.651) ***	0.312 (2.368) *
R-squared	0.764	0.701	0.785	0.496

a: The t statistics are reported in parentheses. "*","**","***", represents 95%, 97.5% and 99% significant levels. "#" represents variables with 90% significance.

The lagged risk perceptions are significant in Eastern Canadian regions, suggesting that cow-calf producers may have followed PRT to adjust their risk perceptions. Various BSE information indices and time trend play significant roles in the risk perception equation for each region. Therefore, the SARF is confirmed. In terms of different information indices, the gross BSE information and the BSE information addressing scientists mainly play an attenuation role in risk perceptions about BSE while the BSE information addressing government plays an amplifying role. This result, to some extent, reflects the trust held by cow-calf producers in scientists and the distrust in government. The time trend also has a significantly positive role in risk perceptions, suggesting that risk perceptions about BSE are amplifying over time.

The estimated risk perceptions are shown in Figure 5.26. The risk perceptions of cow-calf producers in all regions are rising over time, which is similar to the results of time series data model that cow-calf producers in Western and Eastern Canada have increasing risk perceptions about BSE over time. However, in Ontario and Alberta, BSE risk perceptions are higher and increasing faster than in other regions. The increase in risk perceptions about BSE might be one cause of the increase in cow supply in the post-BSE period.

Figure 5.26 Risk Perceptions of BSE (RPBSE) Based on Panel Data of Slaughter Cow Supplies and the Predictive Difference Approach



5.4 Tests for Hypotheses

The hypotheses tested in time series model and panel data model are as follows:

1. The Social Amplification of Risk Framework (SARF). As shown in Table 5.7, 5.9 and 5.16, both the time series data for Western Canada and Eastern Canada and the regional data about slaughter cow supplies provide support for SARF. Various media information indices play different roles in risk perceptions about BSE. For example, in most regions, the gross BSE information and BSE information addressing scientists play an attenuation role in risk perceptions about BSE while the BSE information addressing government play an amplification role in risk perceptions about BSE. One further conclusion from the regional data is that there are significant regional differences as suggested by the

poolability test. Cow-calf producers in Ontario and Alberta had higher risk perceptions about BSE than those in B.C., Manitoba, Saskatchewan, Quebec and the Atlantic provinces.

2. Prospective Reference Theory (PRT). According to the estimation results of the risk perception equations (Table 5.7 and 5.16), PRT is supported by the regions in Eastern Canada but not in Western Canada, implying that cow-calf producers in Eastern Canada may follow a Bayesian updating for their risk perceptions about BSE while those in Western Canada may not.
3. Self-adjustment of risk perceptions (Kask and Maani, 1992; Liu et al., 1998). It is shown that the time trend variable has a significant positive impact on risk perception equations based on the time series data of Western Canada and Eastern Canada and the regional data, suggesting that cow-calf producers in all regions had increasing risk perceptions about BSE over time.
4. The structural break tests at the BSE outbreak in the second quarter, 2003. A structural break is identified in both regional data and time series data of Western Canada related to slaughter cow supplies. There are no BSE-related structural changes in beef cow inventory equations based on time series data or panel data except B.C./Manitoba/Saskatchewan. This result suggests that the structural changes in the cow-calf operations are mainly from slaughter cow supply changes due to BSE outbreak in Western Canada. The underlying behavioural equations (cow inventory equations) are not significantly affected by the BSE outbreak.
5. Feeder calf price ratios (over feed prices) as an indicator of future profit from calf breeding should have a negative impact on slaughter cow supplies and a positive impact on beef cow inventories. On the other hand, slaughter cow price ratios (over feed prices) as an indicator of current profits from cows culled should have a positive impact on slaughter cow supplies and a negative impact on beef cow inventories. These hypotheses about price parameters have been confirmed in the beef cow inventory

equations and slaughter cow supply equations based on the panel data and the time series data.

6. Cow-calf producers will decrease their cattle operations when facing a high risk from slaughter cow prices. Because price risks related to slaughter cows have a positive correlation with slaughter cow supplies, producers in both Western Canada and Eastern Canada prefer to sell their cows for slaughtering when facing increasing price risk related to slaughter cows.
7. Producer subsidy estimates (PSE) post BSE outbreak should have a negative impact on cows culled. This hypothesis has been confirmed in the slaughter cow supply equation.
8. Border re-opening from other countries to Canadian live cattle will affect slaughter cow supplies in Western Canada. As shown in Table 5.5, 5.9 and 5.14, the border re-opening from the U.S. has a positive impact on slaughter cow supplies in Western Canada. The border re-opening from the U.S. to Canadian cattle and bison less than 30 months of age at the third quarter, 2005 only has a significant impact on slaughter cow supplies in Alberta. The border re-opening from the U.S. to all age Canadian cattle in the fourth quarter, 2007 has a significant impact on slaughter cow supplies in Western Canada model and the model for Alberta, B.C./ Manitoba/Saskatchewan.
9. The significant changes in slaughter demand affected the slaughter cow supplies in Canada. As shown in Table 5.14, the significant decreases in slaughter demand in Alberta and B.C./Manitoba/Saskatchewan reduced the slaughter cow supplies in these regions. Specifically, at the periods including the third quarter, 2003 and the first and second quarters, 2005, slaughter cow demand in Alberta was less than 20% of annual monthly average in 12 months in Alberta before BSE outbreak in 2003, leading to a decline in Alberta slaughter cow supplies at the same periods. Similarly, at the periods including the second quarter, 2003, the fourth quarter,2003-the fourth quarter, 2004, slaughter cow demand in B.C./Manitoba/

Saskatchewan was less than 20% of annual monthly average in 12 months in the same regions before BSE outbreak in 2003, leading to a decline in B.C./Manitoba/Saskatchewan slaughter cow supplies at the same periods.

10. Seasonality and time trend. As shown by the significance of parameters associated with quarterly dummies and the time trend variable in Table 5.5, 5.14, seasonality and trend have significant effects on slaughter cow supplies in Western Canada. In Eastern Canada, seasonality plays a significant role on slaughter cow supplies.
11. Dummies for Canada being a signatory to the WTO (or the elimination of Crow Rate) in 1995 and the first Canada-U.S. Free Trade Agreement (CUSTA) in 1988. The dummy for the signing of the WTO (or the elimination of Crow Rate) has a significantly positive impact on beef cow inventory equations for Alberta, B.C./Manitoba/Saskatchewan. The dummy for CUSTA doesn't have any significant impact.

5.5 Comparison with Previous Studies

A comparison of the estimation results of beef cow inventory and slaughter cow supply elasticities in the existing literature is reported (Table 5.17 and Table 5.18). The elasticities of cow supplies with respect to feeder calf prices or cow prices under the predictive difference approach are higher than those in the previous studies for both Western and Eastern Canada (Table 5.17). For Western Canada, the elasticity of cow supply with respect to feeder calf prices under the predictive difference approach becomes larger after the BSE outbreak. The more elastic cow supply related to feeder price may be a result of different specifications such as incorporating the price variations and producer subsidy estimates into the model. The impacts of cow prices, price variations and the producer subsidy estimates on cow supply are also evaluated in this study, as illustrated in the previous sections. The elasticities computed in the state-space approach are of the same signs as those calculated by the predictive difference approach.

Regionally, Western Canada and Eastern Canada are disaggregated into four regions and elasticities in different regions are evaluated. For the entire period, B.C./Manitoba/Saskatchewan and Ontario show the highest elasticities of slaughter cow supply with respect to feeder calf price, cow price or producer subsidy estimates. Ontario shows the highest elasticity of slaughter cow supply with respect to feeder calf or cow price variations. The larger feeder/cow price elasticities post-BSE in Western Canada, Alberta, Quebec/Atlantic provinces indicate that cow-calf producers in these regions may have become more sensitive to feeder calf/cow prices.

Table 5.17 Slaughter Cow Supply Elasticities

Cow supply		Region						
		Western Canada	Eastern Canada	Alta.	B.C.,Man. /Sask	Ont.	Que., Atlan.prov	U.S.
Feeder calf price	Martin and Haack (1977)	-0.420	-0.020	-	-	-	-	-0.210
	Goddard (1979)	-0.600	-0.080	-	-	-	-	-0.330
	Coleman and Meilke (1988)	-0.260	-0.160	-	-	-	-	-0.230
	Cranfield (1995)	-0.330	-0.272	-	-	-	-	-0.313
	John (2007)	-0.291	-0.523	-	-	-	-	-0.326
	This study[a]-PD	-0.649[b]/ -0.716	-0.751/ -0.731	-0.317/ -0.689	-1.010/ -0.526	-1.052/ -0.861	-0.133/ -0.535	-
	This study-SS	-0.843	-1.057	-	-	-	-	-
Cow price	This study- PD	0.428/ 0.522	0.363/ 0.355	0.101/ 0.542	0.734/ 0.317	0.589/ 0.379	0.056/ 0.275	-
	This study-SS	0.633	0.401	-	-	-	-	-
Variance of feeder calf price	This study-PD	-0.056/ -0.048	-0.095/ -0.075	-0.035/ -0.02	-0.069/ -0.104	-0.140/ -0.088	-0.058/ -0.060	-
	This study-SS	-0.024	0.009	-	-	-	-	-
Variance of cow price	This study- PD	0.058/ 0.063	0.100/ 0.090	0.078/ 0.059	0.057/ 0.099	0.157/ 0.110	0.075/ 0.070	-
	This study-SS	0.020	0.011	-	-	-	-	-
Producer subsidy estimates	This study –PD	0.03/ 0.037 post-BSE period: -0.556	0.060/ 0.072 post-BSE period: -0.737	0.029/ 0.036 post-BSE period -0.137	0.054/ 0.053 post-BSE period -0.863	0.106/ 0.036 post-BSE period -1.510	0.082/ 0.103 post-BSE period -0.305	-
	This study -SS	-0.075	-	-	-	-	-	-

a: The prices used in this study is the price ratios between the slaughter cow prices (feeder calf prices) over feed grain prices. "PD" and "SS" represent respectively the predictive difference approach and state-space approach. All the elasticities in this study are computed in the long run.
b: The cell with two elasticity measures represent the long run elastiticity before BSE and the elastiticity based on whole period. "-" represents parameters not available.

The elasticity of beef cow inventory with respect to feeder calf price in Western Canada is similar to other studies (Martin and Haack, 1977; Goddard, 1979)

(Table 5.18). However, for Eastern Canada, the feeder calf price elasticity is larger than the previous studies, possibly because of the difference in estimation periods. Different from previous studies, the impact of cow price on beef cow inventory is also evaluated, as illustrated in the previous sections. Regionally, Western Canada and Eastern Canada are disaggregated into four regions and elasticities in different regions are evaluated. Among four regions, Quebec/Atlantic provinces show the highest elasticity of beef cow inventory with respect to feeder calf price. B.C./Manitoba/Saskatchewan shows the highest elasticity of beef cow inventory with respect to cow price.

Table 5.18 Beef Cow Inventory Elasticities

Beef cow inventory		Region						
		Western Canada	Eastern Canada	Alta.	B.C./Man. /Sask.	Ont.	Que./Atlan. Prov.	U.S.
Feeder price	Tryfos (1974)	0.004	-	-	-	-	-	-
	Freebairn and Rausser (1975)	-	-	-	-	-	-	0.200
	Martin and Haack (1977)	0.200	0.310	-	-	-	-	0.120
	Goddard (1979)	0.210	0.290	-	-	-	-	0.110
	Coleman and Meilke (1988)	0.090	-0.010	-	-	-	-	0.090
	Cranfield (1995)	0.108	0.141	-	-	-	-	0.128
	John (2007)	0.014	0.009	-	-	-	-	0.022
	This study[a]	0.220	0.515	0.142	0.260	0.317	0.966	-
Cow price	This study	-0.304	-	-0.225	-0.333			-

a: The prices used in this study is the price ratios between the slaughter cow prices (feeder calf prices) over feed grain prices. All the elasticities in this study are computed over period 1940-2008. "-" represents parameters not available.

5.6 Chapter Summary

In this chapter Canadian cow-calf producers' reactions to BSE or mad cow disease are discussed. Two types of datasets are applied in the empirical analysis. The first is quarterly time series data including cow inventories, slaughter cow supplies, prices of feeder calf and slaughter cows, variances of prices of feeder calf and slaughter cows, producer subsidy estimates, bank rates, BSE information in Western and Eastern Canada. The other dataset is regionally-augmented panel data with region 1 as Alberta, region 2 as B.C./Manitoba/Saskatchewan, region 3 as Ontario and region 4 as Quebec/Atlantic provinces. BSE information indices including a gross media index and subject media indices are constructed by region to reflect both the quantity and quality aspects of media information. These media information indices are employed in the construction of risk perception equations based on SARF and PRT.

The risk perception equation is then evaluated through two approaches including a predictive difference approach and a state-space approach[60]. The predictive difference approach approximates risk perceptions about BSE by the difference in predictions based on the periods before and after BSE[61] for the slaughter cow supplies. The state-space approach estimates the risk perception equation about BSE and the slaughter cow equation jointly. Both approaches provide empirical justification for SARF, in which cow-calf producers' risk perceptions about BSE are amplified by both the quantity and quality of media information about BSE. The PRT is also supported by the data from Eastern Canada. Different media indices play different roles in cow-calf producers' risk perceptions of BSE. For example, the gross BSE information and the BSE information addressing scientists play an attenuation role while the BSE information addressing government increases risk perceptions. This result to some extent implies the distrust of cow-calf producers in government and trust in scientists. Also, during the collection of media information about BSE, it was identified that BSE information addressing government focused more on the losses of cow-calf producers than BSE information addressing scientists, which probably increased cow-calf producers' risk perceptions about beef cattle operations. Further, different regions show different levels of risk perceptions. The risk perceptions about BSE in all regions are rising over time, suggesting the amplification of risk is continuous over time. In terms of risk perception elasticities, the state-space approach revealed a positive impact of risk perceptions

[60] The state-space approach is only applied to time series data because it didn't work for the panel data.

[61] When there are no enough observations after BSE to estimate the risk perception equation, the whole period including before and after BSE are applied.

on slaughter cow supplies, suggesting that cow-calf producers may be trying to sell their cows in response to increased BSE risk perceptions. Under the predictive difference approach, the parameters of risk perceptions in the slaughter cow supply equation are normalized to one and therefore, the positive values of risk perceptions about BSE estimated by the predictive difference approach also implies that cow-calf producers are trying to sell their cows in response to increased BSE risk perceptions.

The structural break tests are done using both time series data and panel data. A structural break at the time of BSE outbreak in the second quarter of 2003 is tested for and proved by the time series data and regional data on slaughter cow supplies in Western Canada, implying that BSE-related structural breaks mainly occurred in slaughter cow supplies in Western Canada. The beef cow inventories however, didn't show structural breaks in regions except for B.C./Manitoba/Saskatchewan, implying the beef cow inventories of most cow-calf producers may not have been changed significantly by BSE impacts.

The elasticities are estimated over the entire period and the pre-BSE periods for time series data and panel data. The elasticities of slaughter cow supplies with respect to feeder calf price ratios (over feed prices) are negative while that with respect to slaughter cow price ratios are positive. The elasticities of cow supplies with respect to feeder calf prices are higher than those in the previous studies for both Western and Eastern Canada (Table 5.17). In contrast, the elasticities of beef cow inventories with respect to feeder calf prices are positive while those with respect to slaughter cow prices are negative. The elasticities of beef cow inventories with respect to feeder calf prices in this study are higher than those in the previous studies for both Western and Eastern Canada (Table 5.18). As all previous models have shown, cow-calf producers make their decisions according to expected and current profitability. An increase in current profitability will encourage producers to cull their cows while an increase in expected profitability will encourage producers to save their cows for future breeding. The elasticities on price variances (a proxy for price risks) also show different signs in the equations for slaughter cow supplies. The elasticities on price variances of slaughter cows are positive while that on feeder calf prices are negative, implying cow-calf producers respond to increased variability in cow prices by selling more cows while responding to variability in feeder calf prices by holding more cows. Comparing different periods, the elasticities of slaughter cow supply with respect to feeder/cow price are larger in Western Canada, Alberta, Quebec/Atlantic provinces after the BSE outbreak, suggesting that cow-calf producers in these regions become more sensitive to feeder calf or cow prices than before. Parameters estimated by the state-space approach are of the same signs as those estimated by the predictive difference approach.

Other variables except BSE also affect cow-calf producers' slaughter cow supplies or beef cow inventories including producer subsidy estimates, time trend, seasonality as well as a dummy for the time of entering WTO (or elimination of Crow Rate). Specifically, the producer subsidy estimates have a negative impact on slaughter cow supplies during the post-BSE period, suggesting the effectiveness of government policies in encouraging producers to hold their cows longer. The quarterly variables are significant in both the time series model and panel data model, indicating the strong seasonality of cow-calf producers' behaviour. The time trend variable has a significant impact on the equation of slaughter cow supplies from B.C./Manitoba/Saskatchewan, suggesting some industrial structural changes in these regions. The dummies for the time period of Canada entering WTO (or elimination of Crow Rate) (1995) have a significant positive impact on beef cow inventories in Western Canada, Alberta, B.C./Manitoba/Saskatchewan, implying that producers in Western Canadian regions have expanded their cow-calf operations. Also, as indicated by the poolability test, different regions have their specific factors and different production structures.

The border re-opening from other countries to Canadian live cattle and the significant changes in slaughter cow demand in Canada are also examined for their impacts on slaughter cow supplies. A positive impact from the border re-opening from the U.S. to Canadian live cattle on the slaughter cow supplies in Canada is identified while the border re-opening from other countries didn't show significant impacts in Canadian slaughter cow supplies. The significant decreases of slaughter cow demand in Alberta and B.C./Manitoba/Saskatchewan also contributed negatively to the slaughter cow supplies in Alberta and B.C./Manitoba/Saskatchewan, according to the significantly negative parameters of ABSL and BCSL in slaughter cow supply models in Alberta and B.C./Manitoba/Saskatchewan (Table 5.14).

In summary, in this chapter producers' risk perceptions of BSE have been empirically evaluated through slaughter cow supply equations. Risk perceptions are incorporated from a risk perception equation associated with BSE derived from sociological theories such as SARF and PRT. The dynamics of risk perceptions of BSE have been tracked and compared by both a predictive difference approach and a state-space approach. Therefore, this chapter represents an initial attempt to apply a sociological framework such as SARF or PRT to producer risk perception analysis and provides an empirical tool to evaluate producers' risk perceptions through market observable data.

Chapter 6 North American Beef Sector with BSE Impacts

6.1 Introduction

Separate models about consumers or cow-calf producers can be used to test only whether BSE has had an effect on their respective behaviours. To illustrate the significance of their behavioural and risk perception changes, a comprehensive model of the beef sector is needed. BSE impacts within Canada are related to both the U.S. market and the rest of world (ROW) given the highly integrated global beef industry (Caswell and Sparling, 2005). International barriers to trade in beef and live cattle arising from the BSE outbreak have led to significant losses for the Canadian beef industry (Mitura and Di Pietro, 2004; Love, 2005; Le Roy and Klein, 2005; Samarajeewa et al., 2006; John, 2007). Examining the changes in behaviour and risk perceptions in the context of the wider model can allow the determination of the separate effects of trade barriers and changes in risk perceptions. A synthetic model will be constructed with the parameters from this study and previous beef sector studies to illustrate the importance of accounting for risk perception changes as part of the analysis of BSE impacts in Canada.

6.2 Beef and Live Cattle Trade among Canada, the U.S. and the Rest of the World

International trade in cattle and beef is crucial for the industry in Canada. Bilateral trade in beef and live cattle between the U.S. and Canada has grown dramatically over the past twenty years (Brester et al., 2002; Marsh and Peel, 2002; Wachenheim et al., 2004; Marsh et al., 2005). The U.S. is a net importer of both Canadian live cattle and Canadian beef and veal products (Figures 6.1 and 6.2). The reasons for large live cattle exports from Canada to the U.S. have been suggested to be limited slaughter capacity in Canada, the effects of exchange rate differences between Canada and the U.S. and increased livestock production in Canada (Wachenheim et al., 2004). The large export of live cattle from Canada to the U.S. might have also encouraged the growth of livestock production in Canada. However, the BSE-outbreak in Canada had an impact not only on the bilateral beef and cattle trade between the U.S. and Canada but also on the beef trade between Canada and other countries. This can be illustrated in the BSE time lines and trade barriers (Table 6.1).

Table 6.1 The BSE Timeline and Trade Barriers

Time	Trade events
2010-02-25	Seventeenth BSE case confirmed in Alberta
2009-05-15	Sixteenth BSE case confirmed in Alberta
2008-11-17	Fifteenth BSE case confirmed in B.C.
2008-10-20	Mexico reopened border to Alberta breeding cattle.
2008-08-15	Fourteenth BSE case confirmed in Alberta
2008-06-23	Thirteenth BSE case confirmed in B.C.
2007-12-17	Twelveth BSE case confirmed in Alberta.
2007-11	U.S. border was open to all age Canadian cattle
2007-07-12	Enhanced feed ban was implemented. SRMs are prohibited from all feeds for animals, pets and fertilizer use.
2007-06-26	Taiwan lifts ban on Canadian beef imports. The meat is restricted to boneless cuts from cattle under 30 months old.
2007-05-22	Canada has been categorized by the OIE as a Controlled BSE Risk country
2007-05-02	Eleventh BSE case confirmed in B.C.
2007-02-07	Tenth BSE case confirmed in Alberta
2007-02-27	Egypt opens border to Canadian breeding cattle
2006-08-23	Ninth BSE case confirmed in Alberta
2006-07-13	Eighth BSE case confirmed in Alberta
2006-07-04	Seventh BSE case confirmed in a Manitoba cow
2006-06-29	Canada is opening its border to a broader range of animals and animal products from the United States including breeding cattle born after 1999 based on prescribed certification requirements. Beef from cattle over 30 months of age is also eligible for importation under certain conditions.
2006-04-16	Sixth BSE case confirmed in B.C.
2006-02-01	Mexico expanded market access to Canadian beef
2006-01-23	Fifth BSE case confirmed in Alberta
2005-12-11	Japan opened to Canadian beef
2005-07-18	The U.S. border is open to Canadian cattle and bison less than 30 months of age and goats and sheep less than 12 months for immediate slaughter and feeding, as well as a broader range of meat products.
2005-07-08	New Zealand lifted import restrictions on Canadian beef
2005-06-27	Vietnam has opened to Canadian boneless beef under 30 month
2005-03-31	Cuba Re-opened Border to Canadian cattle
2005-03-29	Canada expanded Import Regulations for U.S. Commodities (allow feeder cattle less than 30 months of age import from the U.S.)

2005-01-11	Fourth BSE case confirmed in Alberta
2005-01-02	Third BSE case confirmed in Alberta
2004-12-14	Cuba opened to Canadian beef
2004-12-01	Hong Kong market opened for Canadian beef
2004-04-23	Canadian Amendments permitted broader U.S. meat imports including meats from cattle younger than 30 months of age, boneless and bone-in beef, and various processed products such as ground beef and salami.
2003-12-23	U.S. found the first BSE case
2003-09	As of mid-September, Canadian boneless beef from animals younger than 30 months has been allowed into the United States under a permit process. On October 16 the Minister of Agriculture reported that Canadian companies had shipped 28,000 tonnes of fresh, chilled and frozen beef to the U.S. up to October 15 (Statistics Canada, 2003).
2003-09-09	Russia agreed to resume the import of boneless beef produced from Canadian cattle that are under 30 months and cattle over 30 months if tested and certified negative for BSE.
2003-08-11	Mexico opened its border to Canadian boneless bovine meat from cows under 30 months of age and boneless veal meat from cows nine months of age or younger.
2003-05-20	Second BSE case was found in Alberta; Border closures of the U.S. and all other countries for Canadian beef and live cattle.
1993	A single cow in Red Deer, Alta., was found with BSE.

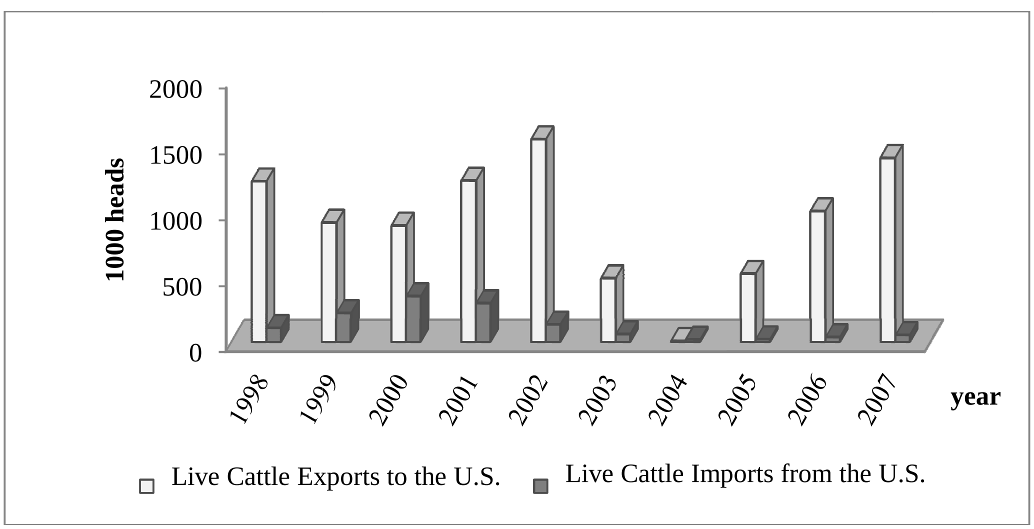
CFIA, http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/bseesbindexe.shtml

After May 2003, the live cattle trade between Canada and the U.S. was stopped and it only recovered partially in 2004 and 2005 but resumed at lower levels than the trade in 2002 (Figure 6.1). The net exports of live cattle from Canada to the U.S. continuously increased from 2005 to 2008. After the re-opening of the US border to Canadian cattle of all ages, the net cattle exports from Canada to the U.S. increased quickly. In terms of beef and veal trade, the net exports of Canadian beef to the U.S. had been increasing before BSE was found in Canada up until in May 2003 (Figure 6.2). Canadian net beef exports to the U.S. declined dramatically in 2003 but recovered partially in 2004 and 2005 due to the opening of the border to trade in beef from animals younger than 30 months in September 2003. From 2006 to 2008, however, Canadian net beef exports to the U.S. declined again, at least partially in response to the higher valued Canadian dollar.

After the BSE discovery in Canada in May 2003, countries such as Japan, South Korea, China, and Russia also cancelled their imports of Canadian beef (Figure 6.3). Others such as Central and South America and the EU(25), decreased their imports of Canadian beef. Mexico, Russia and the U.S. reopened their borders to Canadian beef in 2003 but only to beef from cattle under 30 months. Hong Kong and Cuba opened their borders to Canadian beef at the end of 2004. New Zealand and Vietnam opened their borders to Canadian beef in the middle of 2005. Japan opened its border to Canadian beef at the end of 2005. Mexico also expanded its market access to Canadian beef in February 2007. The countries that opened their borders to Canadian beef imposed certain requirements such as imported beef must come from cattle under 30 months of age and requirements on animal testing. Some countries remain closed to Canadian beef, such as South Korea. Hong Kong and Macau increased their imports from 616 tonnes in 2003 to 10324 tonnes in 2004 and 20368 tonnes in 2005. The Caribbean also increased its imports of Canadian beef and veal from 343 tonnes in 2003 to 17208 tonnes in 2005 and 17675 tonnes in 2008. Mexico increased its imports of Canadian beef from 25917 tonnes in 2003 to 73425 tonnes in 2004 (AAFC, 2008) but declined its imports of Canadian beef after 2004 to 47931 tonnes in 2008.

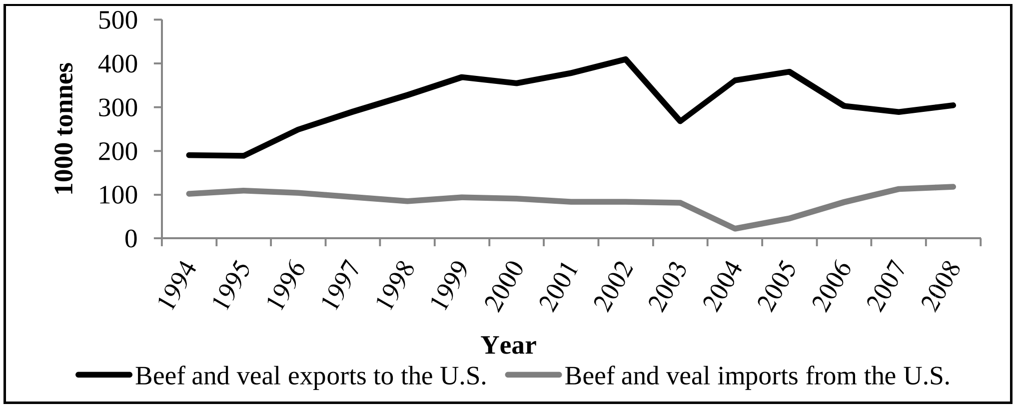
Canadian imports of beef from six major countries decreased temporarily in 2003 (Figure 6.4). After 2003, the beef imports from the U.S. to Canada recovered close to the 2002 level in 2006 and have continuously increased to 2008. The beef imports from Australia and New Zealand declined continuously from 2003 to 2008. Beef imports from Argentina and Brazil increased from 2003 to 2008.

Figure 6.1 Trade in Live Cattle between Canada and the U.S.



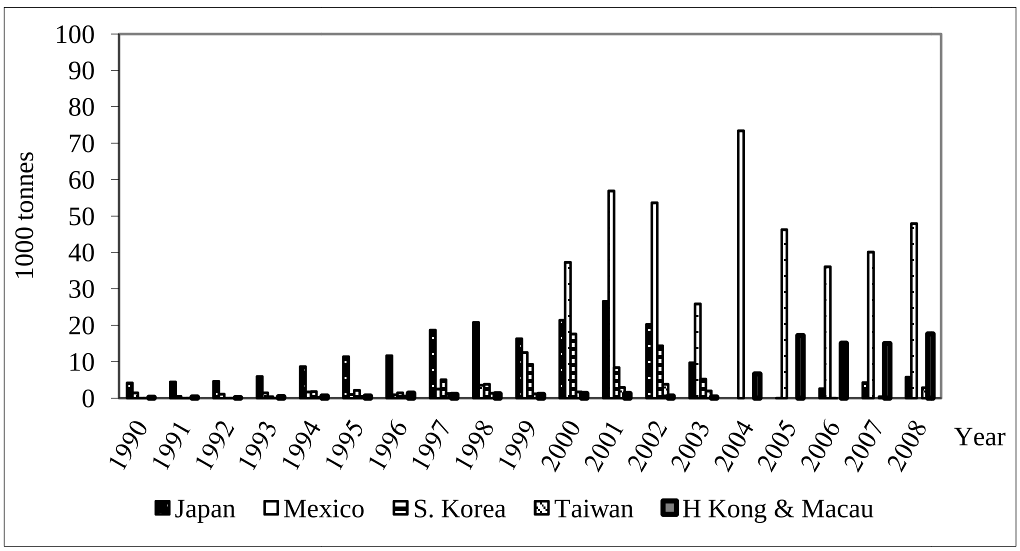
Source: Statistics Canada.

Figure 6.2 Bilateral Trade in Beef and Veal between Canada and the U.S.



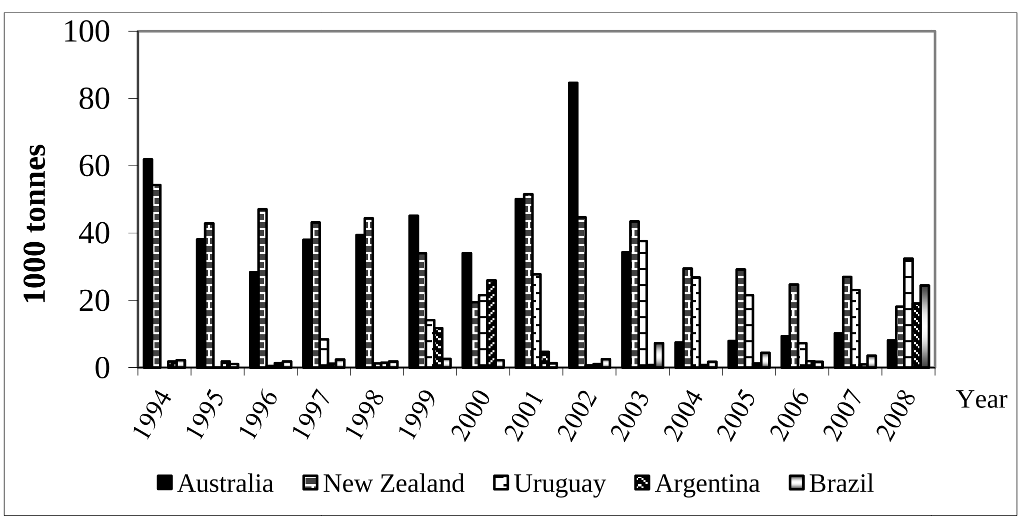
Source: Statistics Canada.

Figure 6.3 Canadian Beef Exports to Countries and Regions except the U.S.



Source: Statistics Canada.

Figure 6.4 Canadian Beef Imports from Countries and Regions except the U.S.



Source: Statistics Canada.

Different countries have had different timelines for opening their border to Canadian beef products (Table 6.1). The international trade in beef and cattle with the U.S. is critical for the beef sector model. However, it may be possible to assume that the net exports of Canadian beef to the rest of the world (ROW) are exogenous for the beef sector model for simulation given their relatively small percentages in the net exports of Canadian beef as compared with the Canadian beef net exports to the U.S. In 2008, around 66% of the Canadian beef net exports were to the U.S.

Circumstances in the North American beef sector were very different in 2008 than they were in 2002, the last year before the BSE crisis changed some relationships permanently. The differences in the key beef sector variables in 2002 and 2008 are provided in Table C.10 in Appendix C. The simulation model to be specified in this chapter is calibrated to 2008 annual data. The model will be used to simulate the impact of what might have occurred if the BSE driven trade shocks had occurred in 2008, with and without the impact of risk perception changes by consumers and cow-calf producers. The simulation results will thus not totally reflect the actual occurrences in 2003/2004.

6.3 Beef Sector Model for Simulation

The beef sector model is specified separately for Western and Eastern Canada and the U.S., considering their different production structures (Martin and Haack, 1977; Coleman and Meilke, 1988; Cranfield and Goddard, 1999; John, 2007). Based on the literature review in Chapter 2 and the summary on page 65 in Chapter 2 the following model specification has been adopted for this simulation model.

Table 6.2 Equations of the Beef Sector Model

Canada	
Cow and bull market	**Steer and heifer market**
Slaughter demand in Western Canada[a]: $D_t^{cb,w} = \gamma_0 + \gamma_1 * \frac{P_t^{cb,w}}{bank_t} + \gamma_2 * \frac{P_t^{r,CA}}{bank_t}$	Slaughter demand in Western Canada: $D_t^{sh,w} = a_0 + a_1 * P_t^{sh,w} + a_2 * P_t^{r,CA}$
Slaughter supply in Western Canada[b]: $S_t^{cb,w} = \delta_0 + \delta_1 * \frac{P_t^{feeder,w}}{P_t^{feed,w}} + \delta_2 * \frac{P_t^{cb,w}}{P_t^{feed,w}} + \delta_3 * RPBSE_t^{w}\text{-}Net\ exports_t^{cb,w}$	Slaughter supply in Western Canada: $S_t^{sh,w} = b_0 + b_1 * P_t^{sh,w} - Net\ exports_t^{sh,w}$
Equilibrium: $D_t^{cb,w} = S_t^{cb,w}$	Equilibrium: $D_t^{sh,w} = S_t^{sh,w}$
Slaughter demand in Eastern Canada: $D_t^{cb,e} = \varphi_0 + \varphi_1 * \frac{P_t^{cb,e}}{bank_t} + \varphi_2 * \frac{P_t^{r,CA}}{bank_t}$	Slaughter demand in Eastern Canada: $D_t^{sh,e} = c_0 + c_1 * P_t^{sh,e} + c_2 * P_t^{r,CA}$
Slaughter supply in Eastern Canada: $S_t^{cb,e} = \tau_0 + \tau_1 * \frac{P_t^{feeder,e}}{P_t^{feed,e}} + \tau_2 * \frac{P_t^{cb,e}}{P_t^{feed,e}} + +\tau_3 * RPBSE_t^{e}\text{-}Net\ exports_t^{cb,e}$	Slaughter supply in Eastern Canada: $S_t^{sh,e} = d_0 + d_1 * P_t^{sh,e}\text{-}Net\ exports_t^{sh,e}$
Equilibrium: $D_t^{cb,e} = S_t^{cb,e}$	Equilibrium: $D_t^{sh,e} = S_t^{sh,e}$
Beef market	
Beef demand in Canada[c]: $D_t^{beef,CA} = \beta_0 + \beta_1 * P_t^{r,CA} + \beta_4 * RPBSE_t^{CA}$;	Revenue from beef sales $R_t^{beef,CA} = D_t^{beef,CA} * P_t^{r,CA}$
Beef supply in Canada: $S_t^{beef,CA} = \left(D_t^{sh,w} + D_t^{sh,e} + D_t^{cb,w} + D_t^{cb,e}\right) * CW_t^{CA} - Net\ exports_t^{beef,CA-US} - Net\ exports_t^{beef,CA-ROW} + Stock\ adjustments^{CA}$ Revenue from slaughter cows and bulls in Western and Eastern Canada: $R_t^{cb,w} = D_t^{cb,w} * CW_t^{CA} * P_t^{r,CA}$; $R_t^{cb,e} = D_t^{cb,e} * CW_t^{CA} * P_t^{r,CA}$ Revenue from slaughter steers and heifers in Western and Eastern Canada: $R_t^{sh,w} = D_t^{sh,w} * CW_t^{CA} * P_t^{r,CA}$; $R_t^{sh,e} = D_t^{sh,e} * CW_t^{CA} * P_t^{r,CA}$	
Market clearing identity for Canada:	
$D_t^{beef,CA} = S_t^{beef,CA}$	
The U.S.[d]	
Cow and bull market	**Steer and heifer market**
Slaughter demand: $D_t^{cb,US} = \theta_0 + \theta_1 * P_t^{cb,US} + \theta_2 * P_t^{r,US}$	Slaughter demand: $D_t^{sh,US} = aa_0 + aa_1 * P_t^{sh,US} + aa_2 * P_t^{r,US}$

Slaughter supply: $S_t^{cb,US} = cc_0 + cc_1 * P_t^{cb,US} + (Net\ exports_t^{cb,w} + Net\ exports_t^{cb,e})$ Equilibrium: $D_t^{cb,US} = S_t^{cb,US}$	Slaughter supply: $S_t^{sh,US} = bb_0 + bb_1 * P_t^{sh,US} + (Net\ exports_t^{sh,w} + Net\ exports_t^{sh,e})$ Equilibrium: $D_t^{sh,US} = S_t^{sh,US}$
Beef market	
Beef demand in the U.S.: $D_t^{beef,US} = \omega_0 + \omega_1 * P_t^{r,US}$	Revenue from beef sales: $R_t^{beef,US} = D_t^{beef,US} * P_t^{r,US}$
Beef supply in the U.S.: $S_t^{beef,US} = \left(D_t^{cb,US} + D_t^{sh,US}\right) * CW_t^{US} + Net\ exports_t^{beef,CA-US} - Net\ exports_t^{beef,US-ROW} + Stock\ adjustments^{US}$ Revenue from slaughter cows and bulls in the U.S. $R_t^{cb,US} = D_t^{cb,US} * CW_t^{US} * P_t^{r,US}$ Revenue from slaughter steers and heifers in the U.S. $R_t^{sh,US} = D_t^{sh,US} * CW_t^{US} * P_t^{r,US}$	
Market clearing identity for the U.S.:	
Market clearing identity for the U.S.: $D_t^{beef,US} = S_t^{beef,US}$	
Price linkages	
Beef price linkage between Canada and the U.S.(μ is the exchange rate between Canada and the U.S.) $P_t^{r,CA} = k_0 + k_1 * P_t^{r,US} * \mu$	
Steer/heifer price linkage between Western Canada (Eastern Canada) and the U.S.: $P_t^{sh,w} = l_{01} + l_{11} * P_t^{sh,US} * \mu$, $P_t^{sh,e} = l_{02} + l_{12} * P_t^{sh,US} * \mu$	
Cow/bull price linkage between Western Canada (Eastern Canada) and the U.S.: $P_t^{cb,w} = v_0 + v_1 * P_t^{cb,US} * \mu$, $P_t^{cb,e} = \rho_0 + \rho_1 * P_t^{cb,US} * \mu$	
Feeder cattle and slaughter steer/heifer price linkage in Canada: $P_t^{feeder,w} = \lambda_0 + \lambda_1 * P_t^{sh,w}$, $P_t^{feeder,e} = \xi_0 + \xi_1 * P_t^{sh,e}$	

a: The slaughter demand for cows/bulls in Eastern Canada and Western Canada are estimated and reported in Appendix E.
b: The slaughter cow supply models for Western and Eastern Canada are reported in Table 5.5. The parameters of BSE risk perceptions are obtained through the state-space approach (Table 5.9).
c: The beef demand model for Canada is reported in Table C.1.
d: The supply and demand models for beef, slaughter cows/bulls and steers/heifers in the U.S. and the price linkage equations are based on the models from Cranfield and Goddard (1999).

Table 6.3 Variable Definitions and Sources

Endogenous Variables		
Variables	Definitions	Sources
$D_t^{cb,w}, D_t^{cb,e}$	Cows and bulls slaughtered in Western or Eastern Canada	AAFC[a]
$D_t^{sh,w}, D_t^{sh,e}$	Steers and heifers slaughtered in Western or Eastern Canada	AAFC
$S_t^{cb,w}, S_t^{cb,e}$	Supply of cows and bulls in Western or Eastern Canada	AAFC
$S_t^{sh,w}, S_t^{sh,e}$	Supply of steers and heifers in Western or Eastern Canada	AAFC
$P_t^{cb,w}, P_t^{cb,e}$	Prices of cows in Western or Eastern Canada	AAFC
$P_t^{sh,w}, P_t^{sh,e}$	Prices of steers in Western or Eastern Canada	AAFC
$P_t^{r,CA}, P_t^{r,US}$	Beef retail prices in Canada or the U.S.	CANSIM and USDA[b]
$P_t^{feeder,w}, P_t^{feeder,e}$	Prices of feeder cattle in Western or Eastern Canada	AAFC
$RPBSE_t^{w}, RPBSE_t^{e}$	Cow-calf producers' BSE risk perceptions in Western or Eastern Canada	Estimates from this study
$Net\ exports_t^{cb,w}$ $Net\ exports_t^{cb,e}$	Net exports of cows and bulls from Western or Eastern Canada to the U.S.	AAFC
$Net\ exports_t^{sh,w}$ $Net\ exports_t^{sh,e}$	Net exports of steers and heifers from Western or Eastern Canada to the U.S.	AAFC
$D_t^{cb,US}, S_t^{cb,US}$	Demand and supply of cows and bulls in the U.S.	AAFC
$P_t^{cb,US}$	Prices of slaughter cows and bulls in the U.S.	USDA
$D_t^{sh,US}, S_t^{sh,US}$	Demand and supply of slaughter steers and heifers in the U.S.	AAFC
$P_t^{sh,US}$	Prices of slaughter steers and heifers in the U.S.	USDA
$D_t^{beef,CA}, D_t^{beef,US}$	Beef demand in Canada or the U.S.	AAFC and USDA
$RPBSE_t^{CA}$	Consumer risk perceptions about BSE in Canada	Estimates from this study
$S_t^{beef,CA}, S_t^{beef,US}$	Beef supply in Canada or the U.S.	AAFC and USDA
$Net\ exports_t^{beef,CA-US}$	Net exports of beef from Canada to the U.S.	AAFC and USDA
$R_t^{cb,w}, R_t^{cb,e}$	Revenue from cows and bulls slaughtered in Western or Eastern Canada	Estimates from this study
$R_t^{sh,w}, R_t^{sh,e}$	Revenue from steers and heifers slaughtered in Western or Eastern Canada	Estimates from this study
$R_t^{sh,US}, R_t^{cb,US}$	Revenue from cows and bulls or steers and heifers slaughtered in the U.S.	Estimates from this study
$R_t^{beef,CA}, R_t^{beef,US}$	Revenue from beef sales in Canada or the U.S.	Estimates from this study
Exogenous Variables		
Variables	Definitions	Sources
$P_t^{barley,w}, P_t^{corn,e}$	Barley prices in Western Canada and corn prices in Eastern Canada	CANSIM II
$bank_t$	Interest rates in Canada	CANSIM
CW_t^{CA}, CW_t^{US}	Carcass weights in Canada or the U.S.	Estimated by $S_t^{beef,CA}/(D_t^{sh,w} + D_t^{sh,e} + D_t^{cb,w} + D_t^{cb,e})$ and $S_t^{beef,US}/D_t^{US}$

$Net\ exports_t^{beef,CA-row}$ $Net\ exports_t^{beef,US-row}$	Net exports of beef from Canada or the U.S. to ROW.	AAFC and USDA
$Stock\ adjustment^{CA}$ $,Stock\ adjustment^{US}$	Beef stock adjustment in Canada or the U.S.	Estimates from this study

a: All the variables used for simulations are from 2008 and are from Red Meat Information Section of AAFC webpage.
b:All the data from USDA are from Red Meat Year Book of USDA webpage.

In addition to the equations in Table 6.2, the risk perception equations related to BSE for Canadian consumers and cow-calf producers are also established as:

$$RPBSE_t^{CA} = z_1 * Gross\ BSE\ information\ index_t + z_2 * BSE\ information\ index\ foucsing\ on\ government_t + z_3 * BSE\ information\ index\ focusing\ on\ scientists_t + z_4 * BSE\ information\ index\ focusing\ on\ affected\ Canadian\ farmers_t \quad (6.1)$$

$$RPBSE_t^{w} = \rho_1 * Gross\ BSE\ information\ index\ in\ Western\ Canada_t + \rho_2 * BSE\ information\ index\ foucsing\ on\ government\ in\ Western\ Canada_t + \rho_3 * BSE\ information\ index\ focusing\ on\ scientists\ in\ Western\ Canada_t \quad (6.2)$$

$$RPBSE_t^{e} = \sigma_1 * Gross\ BSE\ information\ index\ in\ Eastern\ Canada_t + \sigma_2 * BSE\ information\ index\ foucsing\ on\ government\ in\ Western\ Canada_t + \sigma_3 * BSE\ information\ index\ focusing\ on\ scientists\ in\ Western\ Canada_t \quad (6.3)$$

where $RPBSE_t^{CA}$ represents the consumer risk perceptions in Canada. $RPBSE_t^{w}$ and $RPBSE_t^{e}$ represent respectively the producer risk perceptions in Western Canada and Eastern Canada. $RPBSE_t^{CA}$, $RPBSE_t^{w}$ and $RPBSE_t^{e}$ are endogeneous in the beef sector model. BSE information indices are constructed as number of media messages about BSE from various databases including Factiva, Canadian Newsstand, Canadian Reference Centre and ProQuest. BSE information indices are exogenous in the beef sector model. The model system including equations in Table 6.2 and equations 6.1-6.3 is simulated in TSP 5.0. The parameters in every equation are obtained by elasticity estimates from various sources as outlined in Table 6.4.

Table 6.4 Elasticity Estimates and Sources

Elasticities	Estimates	Sources
Unconditional own price elasticity of beef in Canada	-0.45	This study-Chapter 4, Table 4.3, demand model based on period from the first quarter, 1978 to the fourth quarter, 2005
Own price elasticity of beef in the U.S.	-0.285	Cranfield and Goddard (1999)
Beef demand elasticities with respect to risk perceptions about BSE	-0.220	This study-Chapter 4, Table 4.3, demand model based on period from the first quarter, 1978 to the fourth quarter, 2005
Consumer risk perception elasticities with respect to BSE information	2.306	This study-Chapter 4, Table 4.4
Consumer risk perception elasticities with respect to BSE information focusing on government	-0.035	This study-Chapter 4, Table 4.4
Consumer risk perception elasticities with respect to BSE information focusing on scientist	-0.057	This study-Chapter 4, Table 4.4
Consumer risk perception elasticities with respect to BSE information focusing on BSE affected producers	0.007	This study-Chapter 4, Table 4.4
Elasticity of slaughter cow/bull demand with respect to beef retail price in Western Canada	1.370	This study--Appendix E
Elasticity of slaughter cow/bull demand with respect to slaughter cow price in Western Canada	-0.680	This study-Appendix E
Elasticity of slaughter cow/bull supply with respect to the ratio of feeder calf price over barley price in Western Canada	-0.716	This study-Chapter 5, Table 5.6
Elasticity of slaughter cow/bull supply with respect to the ratio of slaughter cow price over barley price in Western Canada	0.522	This study-Chapter 5, Table 5.6
Elasticity of slaughter cow/bull supply elasticity with respect to risk perceptions in Western Canada (slaughter cow supply-risk perceptions)	0.011	This study-Chapter 5, Table 5.10
Elasticity of slaughter cow/bull demand with respect to beef retail price in Eastern Canada	0.410	This study-Appendix E
Elasticity of slaughter cow/bull demand with respect to slaughter cow price in Eastern Canada	-1.680	This study-Appendix E
Elasticity of slaughter cow/bull supply with respect to the ratio of feeder calf price over corn price in Eastern Canada	-0.731	This study-Chapter 5, Table 5.6
Elasticity of slaughter cow/bull supply with respect to the ratio of slaughter cow price over barley price in Eastern Canada	0.355	This study-Chapter 5, Table 5.6
Elasticity of slaughter cow supply with respect to risk perceptions in Eastern Canada (slaughter cow supply-risk perceptions)	0.005	This study-Chapter 5, Table 5.10
Cow-calf producer risk perception elasticities with respect to BSE information in Western Canada	-0.298	This study-Chapter 5, Table 5.8
Cow-calf producer risk perception elasticities with respect to BSE information in Western Canada focusing on government	0.391	This study-Chapter 5, Table 5.8
Cow-calf producer risk perception elasticities with respect to BSE information in Western Canada focusing on scientist	-0.053	This study-Chapter 5, Table 5.8

Cow-calf producer risk perception elasticities with respect to BSE information in Eastern Canada	-0.339	This study-Chapter 5, Table 5.8
Cow-calf producer risk perception elasticities with respect to BSE information in Eastern Canada focusing on government	0.456	This study-Chapter 5, Table 5.8
Cow-calf producer risk perception elasticities with respect to BSE information in Eastern Canada focusing on scientist	0.002	This study-Chapter 5, Table 5.8
Elasticity of slaughter steer/heifer demand with respect to beef retail price in Western Canada	1.085	This study-Appendix E
Elasticity of slaughter steer/heifer demand with respect to slaughter steer/heifer price in Western Canada	-0.751	This study-Appendix E
Elasticity of slaughter steer/heifer supply with respect to slaughter steer/heifer price in Western Canada	0.431	Cranfield and Goddard (1999)
Elasticity of slaughter steer/heifer demand with respect to beef retail price in Eastern Canada	0.930	This study-Appendix E
Elasticity of slaughter steer/heifer demand with respect to slaughter steer/heifer price in Eastern Canada	-0.595	This study-Appendix E
Elasticity of slaughter steer/heifer supply with respect to slaughter steer/heifer price in Eastern Canada	0.191	Cranfield and Goddard (1999)
Elasticity of slaughter steer/heifer demand with respect to beef retail price in the U.S.	0.064	Cranfield and Goddard (1999)
Elasticity of slaughter steer/heifer demand with respect to slaughter steer/heifer price in the U.S.	-0.188	Cranfield and Goddard (1999)
Elasticity of slaughter steer/heifer supply with respect to slaughter steer/heifer price in the U.S.	0.076	Cranfield and Goddard (1999)
Elasticity of slaughter cow/bull demand with respect to beef retail price in the U.S.	0.064	Cranfield and Goddard (1999)
Elasticity of slaughter cow/bull demand with respect to slaughter cow/bull price in the U.S.	-0.188	Cranfield and Goddard (1999)
Elasticity of slaughter cow/bull supply with respect to slaughter cow/bull price in the U.S.	0.076	Cranfield and Goddard (1999)

The slope parameters in all equations are calculated by taking the product of the elasticity and the ratio of the relevant dependent variable to independent variable valued in 2008. The constant in each equation is computed by the dependent variable minus all of the products of the independent variables and their parameters.

6.4 Simulation Scenarios and Results

6.4.1 Simulation Scenarios

The simulations in this chapter are used to show how important risk perception changes are to market outcomes. First, the impacts of trade barriers related to BSE are simulated with the risk perceptions about BSE maintained at their actual historical levels. Then, these simulations are repeated with the endogenous consumer and cow-calf producer risk perceptions about BSE, with risk perceptions reacting to changes in the level of media coverage of BSE. All the simulations in this chapter are "what if" analyses for hypothetical BSE-related barriers occurring in 2008. It is worth noting that the levels of all endogenous variables in the North American beef cattle market are quite different in 2008 than they were in 2002/2003. Hence the impact of examining "what if BSE had happened in 2008" may be quite different than what actually happened in 2002. To highlight how the 2008 reality differs from the 2002 reality the values of all endogenous variables are provided in Table C.10 in Appendix C.

In the first set of simulations, several scenarios are simulated. These include a baseline scenario and a scenario restricting the cattle trade between the U.S. and Canada to zero ($Net\ exports_t^{cb,w} = 0$, $Net\ exports_t^{cb,e} = 0$, $Net\ exports_t^{sh,w} = 0$, $Net\ exports_t^{sh,e} = 0$). The equations concerning price linkages of steers/heifers or cows/bulls between Canada and the U.S. are not included in the simulation. A third scenario is modeled restricting the beef trade between the U.S. and Canada to half of the original amount and restricting the cattle trade between the U.S. and Canada to zero ($Net\ exports_t^{beef,CA-US} = 104.259\ thousand\ tonnes$, $Net\ exports_t^{cb,w} = 0, Net\ exports_t^{cb,e} = 0, Net\ exports_t^{sh,w} = 0, Net\ exports_t^{sh,e} = 0$.) The equations about the price linkages of steers/heifers or cows/bulls between Canada and the U.S. and the beef price linkage between Canada and the U.S. are not included in the simulation. A fourth scenario is modeled restricting the beef trade between Canada and the rest of the world (ROW) to zero ($Net\ exports_t^{beef,CA-ROW} = 0$). The exogenous variables are BSE media coverage and risk perceptions, net beef exports from Canada and the U.S. to the ROW, beef stock adjustments in Canada and the U.S., carcass weights in Canada and the U.S., exchange rates between Canada and the U.S., bank rates and feed grain prices in Canada. Because net beef exports from Canada or the U.S. to the ROW are much smaller than net beef exports from Canada to the US, the assumption that net exports of beef from Canada or the U.S. to the ROW are fixed or exogenous may not have a significant impact on our simulations.

These four scenarios are first simulated with no changes in risk perceptions about BSE by maintaining the BSE media coverage at the 2008 level. The changes in BSE media coverage before and after the periods when the first to the eighth BSE-infected cow were found in Canada are then described later. A lower bound of changes in BSE media coverage, which provides the minimum change in risk perceptions about BSE, is determined and incorporated into the simulation to track the impacts of changes in BSE media coverage on BSE risk perceptions and on endogenous variables in the beef sector model.

6.4.2 Simulation Results

6.4.2.1 Scenario 1: No Cattle Trade between the U.S. and Canada

The simulation results are reported in Table 6.5. The elimination of the cattle trade between Canada and the U.S. (Canada is a net exporter of cattle for the U.S.) leads to decreased cattle supplies in the U.S., which contribute to increased cattle prices and decreased cattle demand in the U.S. As compared to the baseline scenario, the cattle demand or disappearance in the U.S. is decreased by 738 thousand head (-2%), which in turn, leads to a decrease in the beef supplies in the U.S. by 223 thousand tonnes (-2%).

The border closure from the U.S. to Canadian live cattle also implies that more slaughter cattle are supplied in Canada, leading to a decline in Canadian cattle prices and an increase in the slaughter cattle demand in Canada. For example, the slaughter steer/heifer prices in Western Canada and Eastern Canada decline respectively by $0.07/cwt (19%) and $0.14/cwt (34%). The slaughter cow/bull prices in Western Canada and Eastern Canada decline respectively by $0.10/cwt (23%) and $0.05/cwt (10%) (the first, second and fifth columns of Table 6.5). The slaughter cattle demand in Canada increases in response to the decline in slaughter cattle prices. For example, the slaughter steer and heifer demand in Western Canada and Eastern Canada increases respectively by 443 (23%) and 184 (28%) thousand head (the first, second and fifth columns of Table 6.5). The slaughter cow and bull demand in Western Canada and Eastern Canada increases respectively by 161 (26%) and 45 (20%) thousand head (the first, second and fifth columns of Table 6.5). The increase in the slaughter cattle demand in Canada leads to extra beef supplies of 38 thousand tonnes (18%), much of which is exported to the U.S. However, such surplus beef exports to the U.S. cannot compensate for the decrease in US beef supplies and therefore, the beef retail price in the U.S. increases by $0.25 (6%) as compared to the baseline scenario. Beef demand in the U.S. decreases by 224 thousand tonnes (-2%). The beef retail price in Canada also increases by $0.31 (8%), leading beef disappearance in Canada to decrease by 38 thousand tonnes (4%).

The increase in beef retail price and the decrease in beef demand in the U.S. jointly lead to an increase in the revenue from beef sales in the U.S. of $2203 million (4%) as compared to the baseline scenario. The revenues from slaughter cows/bulls and slaughter steers/heifers increase respectively by $427 million (4%) and $1539 million (4%). The revenue from beef sales in Canada also increases by $170 million (4%). The revenue from slaughter cows/bulls and slaughter steers/heifers in Western Canada increases respectively by $329 million (36%) and $938 million (32%). The revenues from slaughter cows/bulls and slaughter steers/heifers in Eastern Canada increase respectively by $97 million (30%) and $372 million (38%). Therefore, cow-calf producers in Western Canada and Eastern Canada might be better off under this scenario.

6.4.2.2 Scenario 2: No Cattle Trade and Half of the Original Beef Trade between Canada and the U.S.

Similar to the first scenario, the border closure to live cattle between Canada and the U.S. requires that more cattle are supplied/slaughtered in Canada, leading to a decline in the slaughter cattle prices in Canada. However, the magnitudes of price decreases in slaughter steers/heifers and slaughter cows/bulls are larger than the first scenario. For example, the slaughter steer/heifer prices in Western Canada and Eastern Canada are decreased respectively by $0.17 (-43%) and $0.26 (-67%). The slaughter cow/bull prices in Western Canada and Eastern Canada are decreased respectively $0.28 (-65%) and $0.13 (-25%).

The slaughter cattle demand in Canada also increases with the decreased cattle prices. For example, the slaughter steer/heifer demand is increased by 168 thousand head (9%) in Western Canada and increased by 127 thousand head

(19%) in Eastern Canada. The slaughter cow/bull demand is increased by 88 thousand head (14%) in Western Canada and increased by 73 thousand head (33%) in Eastern Canada (the first, third and sixth columns of Table 6.5).

Different from the first scenario, the extra beef supplies that are created by the extra slaughter cattle demand in Canada can only be consumed in Canada due to limitations on beef trade between Canada and the U.S., which pushes the Canadian beef price down and encourages more beef disappearance in Canada. Therefore, the beef retail price in Canada decreases by $0.85 (-22%) and the beef disappearance in Canada increases by 104.26 thousand tonnes (10%) as compared to the baseline scenario. The revenue from beef sales in Canada declines by $586 million (-14%) as compared to the baseline scenario. The revenues from slaughter cows/bulls and from slaughter steers/heifers in Western Canada decrease respectively by $95 million (-10%) and $438 million (-15%). The revenue from slaughter cows/bulls in Eastern Canada increases by $14 million (4%) while the revenue from slaughter steers/heifers in Eastern Canada declines by $68 million (-7%).

In the U.S., the border closure to Canadian live cattle and limitations on Canadian beef exports to the U.S. decreases cattle supplies, leading to an increase in slaughter cattle prices and a decrease in slaughter cattle demand. For example, the slaughter cattle demand in the U.S. decreases by 715 thousand head (-2%). The decrease in slaughter cattle demand contributes to a shortage in the beef supplies in the U.S., leading to an increase in the beef price by $0.41 (10%) and a decrease in the beef demanded by 358 thousand tonnes (-3%) in the U.S. The revenue from beef sales in the U.S. increases by $3470 million (7%) as compared with the baseline scenario. The revenues from slaughter cows/bulls and from slaughter steers/heifers in the U.S. increase respectively by $797 million (8%) and $3016 million (8%).

6.4.2.3 Scenario 3: No Beef Trade between Canada and the ROW Assuming No US-Canada Trade Barriers

The border closure from ROW to Canadian beef leads to increased beef supplies in Canada, which contributes to a decline in the beef retail price in Canada of

$0.15 (-4%) as compared to the baseline scenario. The beef demand or disappearance in Canada increases by 18 thousand tonnes (2%). The decline in the beef retail price in Canada leads to a decrease in the slaughter cattle demanded in Canada (the fourth and seventh columns of Table 6.5). For example, the slaughter steer/heifer demand decreases by 59 thousand head (-3%) in Western Canada and decreases by 17 thousand head (-3%) in Eastern Canada. The slaughter cow/bull demand decreases by 24 thousand head (-4%) in Western Canada but increases by 3 thousand head (2%) in Eastern Canada (the fourth and seventh columns of Table 6.5). The prices of slaughter cattle in Canada have very small declines with the decrease in slaughter cattle demand in Canada (the fourth and seventh columns of Table 6.5). The revenue from beef sales in Canada declines by $88 million (-2%). The revenues from slaughter cows/bulls and from slaughter steers/heifers in Western Canada decrease respectively by $69 million (-7%) and $192 million (-7%). The revenues from slaughter cows/bulls and from slaughter steers/heifers in Eastern Canada decrease respectively by $7 million (-2%) and $62 million (-6%).

Given the positive price linkage between Canada and the U.S., the beef retail price decline in Canada also contributes to a decrease in beef retail price in the U.S., which results in an increase in beef demand in the U.S. The slaughter cattle demand in the U.S. decreases, leading to a decline in the slaughter cattle prices in the U.S. The revenue from beef sales in the U.S. declines by $1077 million (-2%). The revenues from slaughter cows/bulls and from slaughter steers/heifers in the U.S. decreases respectively by $275 million (-3%) and $1125 million (-3%).

Table 6.5 Simulation Results for the Canadian and U.S. Beef Sector Model

		Scenarios			Changes from the baseline scenario		
Scenarios	Baseline scenario	No trade in cattle between Canada and the US	No trade in cattle and half of the original beef trade between Canada and the US	No trade in beef between Canada and the ROW	No trade in cattle between Canada and the US	No trade in cattle and half of the original beef trade between Canada and the US	No trade in beef between Canada and the ROW
Beef disappearance in Canada (1000 tonnes)	1063.900	1025.675	1168.159	1081.884	-3.59%	9.80%	1.69%
Beef retail prices in Canada[a]	3.906	4.217	3.055	3.759	7.98%	-21.78%	-3.76%

($ /kg)							
Slaughter steer and heifer demand in Western Canada (1000 head)	1970.035	2413.368	2138.913	1911.216	22.50%	8.57%	-2.99%
Slaughter cow and bull demand in Western Canada (1000 head)	612.870	773.790	701.367	588.552	26.26%	14.44%	-3.97%
Slaughter steer and heifer demand in Eastern Canada (1000 head)	667.426	851.243	794.651	650.139	27.54%	19.06%	-2.59%
Slaughter cow and bull demand in Eastern Canada (1000 head)	217.928	262.409	290.911	221.373	20.41%	33.49%	1.58%
Price of slaughter steers and heifers in Western Canada ($/cwt)	0.392	0.319	0.224	0.386	-18.51%	-42.79%	-1.43%
Price of slaughter steers and heifers in Eastern Canada ($/cwt)	0.393	0.259	0.131	0.387	-34.10%	-66.64%	-1.53%
Price of slaughter cows and bulls in Western Canada ($/cwt)	0.436	0.337	0.152	0.428	-22.53%	-65.11%	-1.73%
Price of slaughter cows and bulls in Eastern Canada ($/cwt)	0.503	0.452	0.376	0.494	-10.20%	-25.25%	-1.86%
Beef disappearance in the U.S. (1000 tonnes)	12384.043	12160.213	12026.009	12489.351	-1.81%	-2.89%	0.85%
Beef retail prices in the U.S. ($ /kg)	4.026	4.281	4.434	3.905	6.34%	10.14%	-2.98%
Slaughter steer and heifer demand in the U.S. (1000 head)	27253.492	26640.686	26659.326	27280.059	-2.25%	-2.18%	0.10%
Slaughter cow and bull demand in the U.S. (1000 head)	6808.961	6683.706	6688.382	6819.788	-1.84%	-1.77%	0.16%
Price of slaughter steers and heifers in the U.S. ($/cwt)	0.393	0.448	0.452	0.387	14.12%	15.05%	-1.53%
Price of slaughter cows and bulls in the U.S. ($/cwt)	0.481	0.539	0.543	0.472	11.94%	12.87%	-1.86%
Revenue from cow and bull slaughtering in Western Canada (million $)	904.356	1232.975	809.562	835.849	36.34%	-10.48%	-7.58%
Revenue from steer and heifer slaughtering in Western Canada	2906.999	3845.520	2468.868	2714.265	32.28%	-15.07%	-6.63%

(million $)							
Revenue from cow and bull slaughtering in Eastern Canada (million $)	321.576	418.129	335.787	314.389	30.02%	4.42%	-2.23%
Revenue from steer and heifer slaughtering in Eastern Canada (million $)	984.859	1356.391	917.236	923.312	37.72%	-6.87%	-6.25%
Revenue from cow and bull slaughtering in the U.S. (million $)	9732.167	10158.975	10529.588	9456.805	4.39%	8.19%	-2.83%
Revenue from steer and heifer slaughtering in the U.S. (million $)	38953.895	40492.816	41970.047	37828.477	3.95%	7.74%	-2.89%
Revenue from beef sales in Canada (million $)	4155.212	4325.763	3568.850	4066.726	4.10%	-14.11%	-2.13%
Revenue from beef sales the U.S. (million $)	49853.121	52056.500	53322.805	48776.941	4.42%	6.96%	-2.16%
Risk perceptions about BSE for Canadian consumers	0.047	0.047	0.047	0.047	0.00%	0.00%	0.00%
Risk perceptions about BSE for cow-calf producers in Western Canada	0.650	0.650	0.650	0.650	0.00%	0.00%	0.00%
Risk perceptions about BSE for cow-calf producers in Eastern Canada	1.746	1.746	1.746	1.746	0.00%	0.00%	0.00%

a: all prices are adjusted by consumer price indices.

These changes in beef cattle sector variables are similar but not identical to the actual impacts on the North American market that occurred in 2003. Given that the level of slaughter steer and heifer trade with the US in 2008 was actually higher and the level of slaughter cow and bull trade with the U.S. in 2008 was actually lower than those in 2002, the impacts of closing the border are different – with a bigger impact on steer/heifer slaughter prices in Canada, for example, and a smaller impact on cow/bull slaughter prices than actually occurred in 2003. As well these simulations each illustrate a separate part of the combined trade barriers that impacted the market in 2003. In 2003 there was simultaneous closure of North American trade in cattle and in beef and closure of international markets to Canadian beef. For these simulations each of these impacts are simulated separately, highlighting the relative importance of trade in cattle, trade in beef in North America and trade in beef with the ROW to the Canadian market.

6.4.2.4 Simulation of the Effects of Changes in Risk Perceptions about BSE

As shown in previous chapters, risk perceptions about BSE will also affect consumer and cow-calf producer behaviour. To evaluate the impacts of BSE risk perceptions of Canadian consumers and producers on the Canadian and the U.S. beef sector, the three scenarios in the last section are re-simulated with a change in BSE risk perceptions. Because Canadian BSE risk perceptions are driven by the Canadian media coverage about BSE, it is possible to estimate a lower bound for changes in BSE media coverage from historical data on changes in the number of articles at particular points in time. This selected lower bound can be used to change risk perceptions and to evaluate the impacts of BSE risk perception changes on Canadian and the U.S. beef sectors. The changes in BSE media coverage are reported (Table 6.6).

Table 6.6 Changes in the Media Coverage about BSE in Canada before and after BSE Outbreaks

<table>
<tr><td colspan="6">BSE media coverage for Canadian consumers</td></tr>
<tr><td>BSE-infected cow were found</td><td>Year: month</td><td>Gross BSE information</td><td>BSE information addressing government</td><td>BSE information addressing scientists</td><td>BSE information addressing BSE affected producers</td></tr>
<tr><td>The first</td><td>1993:12</td><td>600%</td><td>300%</td><td>300%</td><td>100%</td></tr>
<tr><td>The second</td><td>2003:05</td><td>3623%</td><td>7814%</td><td>2075%</td><td>26733%</td></tr>
<tr><td>The third and fourth</td><td>2005:01</td><td>141%</td><td>148%</td><td>1084%</td><td>138%</td></tr>
<tr><td>The fifth</td><td>2006:01</td><td>39%</td><td>42%</td><td>47%</td><td>25%</td></tr>
<tr><td>The sixth</td><td>2006:04</td><td>26%</td><td>40%</td><td>38%</td><td>31%</td></tr>
<tr><td>The seventh and eighth</td><td>2006:07</td><td>7%</td><td>6%</td><td>5%</td><td>6%</td></tr>
<tr><td colspan="6">BSE media coverage for the cow-calf producers in Western Canada</td></tr>
<tr><td>BSE-infected cow were found</td><td>Year: month</td><td>Gross BSE information</td><td>BSE information addressing government</td><td colspan="2">BSE information addressing scientists</td></tr>
<tr><td>The first</td><td>1993:12</td><td>300%</td><td>0%</td><td colspan="2">0%</td></tr>
<tr><td>The second</td><td>2003:05</td><td>14450%</td><td>10500%</td><td colspan="2">2900%</td></tr>
<tr><td>The third and fourth</td><td>2005:01</td><td>276%</td><td>205%</td><td colspan="2">1500%</td></tr>
<tr><td>The fifth</td><td>2006:01</td><td>30%</td><td>64%</td><td colspan="2">50%</td></tr>
<tr><td>The sixth</td><td>2006:04</td><td>20%</td><td>47%</td><td colspan="2">35%</td></tr>
<tr><td>The seventh and eighth</td><td>2006:07</td><td>4%</td><td>5%</td><td colspan="2">10%</td></tr>
<tr><td colspan="6">BSE media coverage for the cow-calf producers in Eastern Canada</td></tr>
<tr><td>BSE-infected cow were</td><td>Year: month</td><td>Gross BSE information</td><td>BSE information addressing</td><td colspan="2">BSE information addressing scientists</td></tr>
</table>

found			government	
The first	1993:12	300%	0%	0%
The second	2003:05	8043%	11700%	3200%
The third and fourth	2005:01	253%	139%	550%
The fifth	2006:01	37%	75%	50%
The sixth	2006:04	17%	35%	32%
The seventh and eighth	2006:07	3%	8%	9%

Note: the changes in the media coverage about BSE is calculated by the number of media messages about BSE at the quarter when the BSE-infected cow was found divided by the number of media information about BSE at the quarter before the BSE-infected cow was found and minus 1.

Before and after the discoveries of the first to the eighth BSE-infected cows in Canada, the BSE media coverage in Canada has increased by different magnitudes. For example, there was a very large increase in the media coverage about BSE after the second BSE-infected cow was found in Canada in May, 2003, while there was a very small increase in the media coverage about BSE in Canada after the seventh and the eighth BSE-infected cows were found in Canada in July, 2006. To track the effects of the changes in risk perceptions, we make use of the increases in BSE media coverage before and after July 2006 as an example of the potential change in BSE media coverage to determine changes in risk perceptions about BSE for consumers and producers and to simulate the various trade barrier scenarios again. The use of changes in BSE media coverage before and after July 2006 when the seventh and eighth BSE-infected cows were found is because these media coverage changes around BSE discoveries are closest to the data used for the simulation in this study and may reflect the changes of BSE media coverage during the simulation period. The simulation results are reported (Table 6.7). A comparison between Table 6.7 and Table 6.5 reveals that the changes in each variable in each scenario is of the same direction whether there is a change in risk perceptions or not. However, the magnitude of changes is different, these changes are reported (Table 6.8).

Table 6.7 Simulation Results of the Canadian and U.S. Beef Sector Model with Changes in BSE Risk Perceptions

Scenarios	Baseline scenario	Scenarios			Changes from the baseline scenario		
		No trade in cattle between Canada and the US	No trade in cattle and half of the original beef trade between Canada and the US	No trade in beef between Canada and the ROW	No trade in cattle between Canada and the US	No trade in cattle and half of the original beef trade between Canada and the US	No trade in beef between Canada and the ROW
Beef disappearance in Canada (1000 tonnes)	1063.900	1011.431	1168.159	1068.054	-4.93%	9.80%	0.39%
Beef retail price in Canada[a] ($/kg)	3.906	4.199	2.920	3.737	7.51%	-25.23%	-4.32%
Slaughter steer and heifer demand in Western Canada (1000 head)	1970.035	2408.955	2107.064	1902.371	22.28%	6.96%	-3.43%
Slaughter cow and bull demand in Western Canada (1000 head)	612.870	772.635	692.973	584.902	26.07%	13.07%	-4.56%
Slaughter steer and heifer demand in Eastern Canada (1000 head)	667.426	850.333	788.084	647.540	27.40%	18.08%	-2.98%
Slaughter cow and bull demand in Eastern Canada (1000 head)	217.928	262.892	294.243	221.898	20.63%	35.02%	1.82%
Price of slaughter steers and heifers in Western Canada ($/cwt)	0.392	0.318	0.213	0.385	-18.90%	-45.61%	-1.64%
Price of slaughter steers and heifers in Eastern Canada ($/cwt)	0.393	0.257	0.116	0.386	-34.62%	-70.41%	-1.76%
Price of slaughter cows and bulls in Western Canada ($/cwt)	0.436	0.335	0.130	0.427	-23.21%	-70.05%	-1.99%
Price of slaughter cows and bulls in Eastern Canada ($/cwt)	0.503	0.450	0.367	0.492	-10.45%	-27.00%	-2.14%
Beef disappearance in the U.S. (1000 tonnes)	12384.04	12173.63	12026.01	12505.18	-1.70%	-2.89%	0.98%
Beef retail prices in the U.S. ($ /kg)	4.03	4.27	4.43	3.89	5.96%	10.14%	-3.43%
Slaughter steer and heifer demand in the U.S. (1000 head)	27253.49	26638.82	26659.33	27284.05	-2.26%	-2.18%	0.11%

Slaughter cow and bull demand in the U.S. (1000 head)	6808.96	6683.24	6688.38	6821.42	-1.85%	-1.77%	0.18%
Price of slaughter steers and heifers in the U.S. ($/cwt)	0.39	0.45	0.45	0.39	14.03%	15.05%	-1.76%
Price of slaughter cows and bulls in the U.S. ($/cwt)	0.48	0.54	0.54	0.47	11.85%	12.87%	-2.14%
Revenue from cow and bull slaughtering in Western Canada (million $)	904.356	1225.680	764.557	825.790	35.53%	-15.46%	-8.69%
Revenue from steer and heifer slaughtering in Western Canada (million $)	2906.999	3821.476	2324.725	2685.849	31.46%	-20.03%	-7.61%
Revenue from cow and bull slaughtering in Eastern Canada (million $)	321.576	417.042	324.638	313.284	29.69%	0.95%	-2.58%
Revenue from steer and heifer slaughtering in Eastern Canada (million $)	984.859	1348.937	869.493	914.224	36.97%	-11.71%	-7.17%
Revenue from cow and bull slaughtering in the U.S. (million $)	9732.167	10121.954	10529.588	9415.350	4.01%	8.19%	-3.26%
Revenue from steer and heifer slaughtering in the U.S. (million $)	38953.895	40345.254	41970.047	37659.059	3.57%	7.74%	-3.32%
Revenue from beef sales in Canada (million $)	4155.212	4246.787	3411.280	3991.176	2.20%	-17.90%	-3.95%
Revenue from beef sales the U.S. (million $)	49853.121	51927.652	53322.805	48612.938	4.16%	6.96%	-2.49%
Risk perceptions about BSE for Canadian consumers	0.047	0.050	0.050	0.050	6.40%	6.40%	6.40%
Risk perceptions about BSE for cow-calf producers in Western Canada	0.650	0.687	0.687	0.687	5.70%	5.70%	5.70%
Risk perceptions about BSE for cow-calf producers in Eastern Canada	1.745	2.134	2.134	2.134	22.20%	22.20%	22.20%

a: all prices are adjusted by consumer price indices.

Table 6.8 Changes in Simulation Results due to the Changes in BSE Risk Perceptions in Canada

Scenario / Variable	The difference in simulation results for each scenario with and without changes in BSE media coverage: $\frac{(x_{scenario\ i}^{changed\ Risk\ Perceptions\ about\ BSE} - x_{scenario\ i}^{orignial\ simulation})}{x_{scenario\ i}^{orignial\ simulation}}$		
	No trade in cattle between Canada and the US	No trade in cattle and half of the original beef trade between Canada and the US	No trade in beef between Canada and the ROW
Beef disappearance in Canada (1000 tonnes)	-1.39%	-2.3%	-1.28%
Beef retail price in Canada ($ /kg)	-0.44%	-4.42%	-0.59%
Slaughter steer and heifer demand in Western Canada (1000 head)	-0.18%	-1.49%	-0.46%
Slaughter cow and bull demand in Western Canada (1000 head)	-0.15%	-1.22%	-0.62%
Slaughter steer and heifer demand in Eastern Canada (1000 head)	-0.11%	-0.83%	-0.40%
Slaughter cow and bull demand in Eastern Canada (1000 head)	0.18%	1.15%	0.24%
Price of slaughter steers and heifers in Western Canada ($ /cwt)	-0.48%	-4.92%	-0.22%
Price of slaughter steers and heifers in Eastern Canada ($ /cwt)	-0.79%	-11.32%	-0.24%
Price of slaughter cows and bulls in Western Canada ($ /cwt)	-0.89%	-14.17%	-0.27%
Price of slaughter cows and bulls in Eastern Canada ($ /cwt)	-0.28%	-2.35%	-0.29%
Beef disappearance in the U.S. (1000 tonnes)	0.11%	0.00%	0.13%
Beef retail price in the U.S. ($ /kg)	-0.36%	0.00%	-0.46%
Slaughter steer and heifer demand in the U.S. (1000 head)	-0.01%	0.00%	0.01%
Slaughter cow and bull demand in the U.S. (1000 head)	-0.01%	0.00%	0.02%
Price of slaughter steers and heifers in the U.S. ($ /cwt)	-0.08%	0.00%	-0.24%
Price of slaughter cows and bulls in the U.S. ($ /cwt)	-0.08%	0.00%	-0.29%
Revenue from cow and bull slaughtering in Western Canada (million $)	-0.59%	-5.56%	-1.20%
Revenue from steer and heifer	-0.63%	-5.84%	-1.05%

slaughtering in Western Canada (million $)			
Revenue from cow and bull slaughtering in Eastern Canada (million $)	-0.26%	-3.32%	-0.35%
Revenue from steer and heifer slaughtering in Eastern Canada (million $)	-0.55%	-5.21%	-0.98%
Revenue from cow and bull slaughtering in the U.S. (million $)	-0.36%	0.00%	-0.44%
Revenue from steer and heifer slaughtering in the U.S. (million $)	-0.36%	0.00%	-0.45%
Revenue from beef sales in Canada (million $)	-1.83%	-4.42%	-1.86%
Revenue from beef sales in the U.S. (million $)	-0.25%	0.00%	-0.34%
Risk perceptions about BSE for Canadian consumers	6.40%	6.40%	6.40%
Risk perceptions about BSE for cow-calf producers in Western Canada	5.70%	5.70%	5.70%
Risk perceptions about BSE for cow-calf producers in Eastern Canada	22.20%	22.20%	22.20%

Risk perceptions related to BSE for Canadian cow-calf producers and consumers increase in response to increases in media information about BSE in Western and Eastern Canada. Under the scenario with no cattle trade between Canada and the U.S., the increases in consumer and producer risk perceptions have a negative impact on most of the variables. For example, the increases in consumer and producer risk perceptions result in beef disappearance decreasing by 1.4% and the beef retail price by 0.4% as compared to the first set of simulation results. The slaughter steer/heifer demands in Western Canada and Eastern Canada decrease, respectively, by 0.2% and 0.1%. Slaughter cow/bull demand in Western Canada decreases by 0.2% while that in Eastern Canada increases by 0.2%. Slaughter cattle price also decreases (the second column of Table 6.8). The revenues from beef sales in Canada and the U.S. decrease respectively by 1.8% and 0.3%. Revenues from slaughter cows/bulls and slaughter steers/heifers in Western Canada decrease, respectively, by 0.6%. Revenues from slaughter cows/bulls and slaughter steers/heifers in Eastern Canada decrease, respectively, by 0.3% and 0.6%.

Under the scenario with no cattle trade between Canada and the U.S. and half of the original beef trade between Canada and the U.S., the increases in consumer and producer risk perceptions lead to even larger cattle supplies in Canada. This , in turn, results in a large decline in slaughter cattle prices (the third column of Table 6.8) in Canada as compared to the simulation result with no changes in BSE risk perceptions. The increases in risk perceptions also lead to a decline in consumer beef demand in Canada (-2.3%), which contributes to a decline in beef retail price in Canada (-4.4%). Slaughter cattle demand also decline (the third column of Table 6.8). The revenue from beef sales in Canada decreases by 4.4% while that in the U.S. is unchanged. The revenues from slaughter cows/bulls and slaughter steers/heifers in Western Canada decrease respectively by 5.6% and 5.8%. The revenues from slaughter cows/bulls and slaughter steers/heifers in Eastern Canada decrease respectively by 3.3% and 5.2%.

Under the scenario with no trade in beef between Canada and the ROW, the increases in consumer and producer risk perceptions also lead to a decrease in all variables. However, the magnitudes of change is lower as compared to the scenario restricting the cattle trade between Canada and the U.S. to zero and limiting the beef trade between Canada and the U.S. to half of its original amount. Revenues from beef sales in Canada and the U.S. decrease, respectively, by 1.9% and 0.3%. Revenues from slaughter cows/bulls and slaughter steers/heifers in Western Canada decrease, respectively, by 1.2% and 1.1%. Revenues from slaughter cows/bulls and slaughter steers/heifers in Eastern Canada decrease, respectively, by 0.4% and 1%.

The comparisons with and without changes in risk perceptions about BSE reveal regional differences in demand and price responses of slaughter cattle. In all scenarios, Eastern Canadian producers have larger price decreases but smaller declines in revenue in slaughter steers/heifers due to increases in risk perceptions about BSE as compared to Western Canadian producers. As shown in Table C.10, the exports of steer and heifers from Eastern Canada to the U.S. are 44% larger in 2008 as compared to in 2002 while those from Western Canada to the U.S. are 15% larger in 2008 as compared to in 2002 although the number of steer and heifer exports from Eastern Canada to the U.S. are much smaller than that from Western Canada to the U.S. A higher reliance by Eastern Canada on slaughter steer and heifer exports as compared to Western Canada will lead to a larger price decline in slaughter steer and heifer prices in Eastern Canada when these exports are reduced.

In all scenarios, the increases in Canadian consumer and producer risk perceptions about BSE contribute to declines in beef demand and extra cattle supplies in Canada. This results in losses in beef and cattle sales in Canada, suggesting a significant impact of SARF in the Canadian beef sector. The loss of beef sales in Canada from changed risk perceptions ranges from 1.8% to 4.4%. As compared to the first simulation results, the loss in slaughter cow/bull sales ranges from 0.6% to 5.6% in Western Canada and from 0.3% to 4% in Eastern Canada. The loss in slaughter steer/heifer sales ranges from 0.6% to 6% in Western Canada and from 0.6% to 5.2% in Eastern Canada depending upon the particular trade barrier imposed. The beef disappearance in Canada is also affected by changes in risk perceptions, perhaps more by risk perception changes of consumers–disappearance differences between the two sets of simulations range from -1.3% to -2.3%.

Risk perception changes, in the case of an extraordinary risky event, have the potential to make market outcomes worse than they might be without such perception changes. This implies the importance of risk communication messages both before and after the occurrence of such a risky event. Leiss and Nichol (2006) point out that the government's risk communication "failed to point out the nature and scope of the … true 'catastrophic' risk of the discovery of even a single case of BSE in the Canadian beef herd for the entire group of small independent beef producers" (page 891). Understanding the framing of government, scientists and farmers in media coverage for consumers and producers can be important for governments and industry groups in designing better risk communication strategies for a risk event. For cow-calf farmers, more effective risk communications to reduce the negative image of government is required. There are clearly different impressions about the role and responsibility of government in handling risky events such as BSE held by producers versus consumers, further analysis of why and how these views are held would be important in developing future risk management strategies. For consumers, BSE information from government can reduce their risk perceptions. Therefore, more government focused BSE information may help rebuild trust in beef safety.

6.5 Chapter Summary

A synthetic model is constructed in this chapter and used for the simulations of the Canadian and the U.S. beef sector. Four scenarios are simulated including a baseline scenario, a scenario restricting cattle trade between Canada and the U.S. to zero, a scenario restricting cattle trade between Canada and the U.S. to zero and limiting beef trade between Canada and the U.S. to half of the original, and a scenario restricting the beef trade between Canada and the rest of the world to zero. These scenarios are "what if" analyses for hypothetical BSE-related border closures in 2008.

Among the three scenarios, the scenario with zero cattle trade and limited beef trade between Canada and the U.S. produces the largest decline in beef retail prices and beef sales revenue in Canada and the largest increase in beef retail price and beef sales revenue in the U.S. Other variables such as slaughter cattle prices and slaughter cattle revenues also differ the most with this scenario. The scenario restricting the beef trade between Canada and the rest of the world shows the least change in all variables such as the decline in beef retail price, slaughter cattle prices and beef sales revenue. These results suggest that a border closure from the U.S. to Canadian live cattle and a partial restriction on beef exports from Canada to the U.S. will have much larger impacts on Canadian and U.S. beef sectors as compared to a border closure to Canadian live cattle only and border closures from other countries to Canadian beef. The beef trade between Canada and the rest of the world has the least impact on Canadian and the U.S. beef sectors, based on current market conditions. Because net beef exports from Canada or the U.S. to the ROW are much smaller than net beef exports from Canada to the US, the assumption that net exports of beef from Canada or the U.S. to the ROW are fixed or exogenous may not have a significant impact on our simulations.

To track the impacts of the risk perception changes about BSE in Canada, each scenario is also simulated by increasing BSE media coverage according to the percentage increase in BSE media coverage that occurred when the seventh and eighth BSE-infected cows were found in Canada in July, 2006. It is suggested by the comparison that an increase in consumer and producer risk perceptions about BSE in Canada has a negative impact on most variables in the Canadian beef sector such as beef disappearance, beef retail price, slaughter steer/heifer demand and prices, slaughter cow/bull demand. From the consumer side, enhanced risk perceptions about BSE lead to a decrease in beef demand and beef retail prices in Canada. Such a decrease in beef retail price also contributes to a decrease in slaughter cattle demand and prices in Canada. From the cow-calf producer side, an increase in risk perceptions about BSE leads to an increase in slaughter cattle supplies and a further decrease in slaughter cattle prices in Canada. Such a decrease in slaughter cow/bull price will contribute to an increase in slaughter cattle demand. The mixed effects from the decrease in beef retail price and slaughter cattle prices on slaughter cattle demand are negative except for the slaughter cow/bull demand in Eastern Canada. The slaughter cow/bull supplies in Eastern Canada are largely from dairy cows and prices of milk products may affect the supplies and demand of cull cows/bulls in Eastern Canada as well.

Risk perceptions about BSE cause losses in beef and cattle revenue in Canada, implying certain impacts of SARF on Canadian beef sector. Due specifically to the changes in risk perceptions about BSE, the losses in beef sales revenue in Canada can be as large as 4.4%. The losses in slaughter steer/heifer sales revenue can be as large as 5.8% in Western Canada and 5.2% in Eastern Canada. The losses in slaughter cow/bull sales revenue can be as large as 5.6% in Western Canada and 3.3% in Eastern Canada.

In summary, in this chapter results of simulating the impacts of border closures to Canadian live cattle and beef products in the U.S. and to beef products in the ROW on the North American beef sector are shown. Behavioural changes of cow-calf producers and consumers are tracked through various scenarios. Furthermore, the impacts of changing risk perceptions related to BSE on the Canadian beef sector are incorporated into the simulation model. An empirical assessment of the impacts of risk perceptions about BSE by Canadian consumers and cow-calf producers is provided and the impacts of SARF are measured by comparing each scenario with and without changed risk perceptions about BSE. The BSE risk perception changes add significantly to losses in the Canadian beef sector and governments need better risk communication strategies in handling a similar animal disease in the future. In summary, this chapter provides information for government decision-makers to evaluate the impacts of border closures from other countries to Canadian beef and live cattle and the impacts of SARF on a risky event on the entire North American beef sector.

Chapter 7 Summary and Future Work

7.1 Introduction

BSE can alter consumers' risk perceptions about beef consumption and producers' risk perceptions about beef cattle operations. Such changes may affect the market behaviour of consumers and producers and create shocks for a beef supply chain. A BSE-related border closure from other countries to Canadian beef and live cattle can add more uncertainty in the Canadian beef industry. An integrated North-American beef and live cattle market may result in a shock occurring in the Canadian beef sector being felt in the U.S. beef sector as well (Caswell and Sparling, 2005). It is unforeseeable whether more disease outbreaks will occur and it remains a problem as to how public policy should react to these outbreaks appropriately. Given these issues, government decision-makers and industry stakeholders need certain quantitative information about the severity of the risks associated with the disease and the changes in consumer and producer behaviour. This thesis is therefore, aimed at analyzing these issues and providing some quantitative measurements for these impacts. The specific objectives in this thesis are to:

1. Construct and estimate a consumer demand model to examine the BSE impacts, study the evolution of risk perceptions about BSE and quantify the effect of media coverage on BSE risk perceptions of beef consumers in Canada. Structural breaks due to BSE will also be tested for in the consumer demand models by both parametric and non-parametric approaches.
2. Construct and estimate a cow-calf producer model (including beef cow inventory equations and slaughter cow supply equations) to examine the BSE impacts, study the evolution of producers' risk perceptions about BSE and quantify the effects of media coverage on BSE risk perceptions of cow-calf producers in Canada. Structural breaks due to BSE will also be tested for based on the cow-calf producer model.

3. Develop a beef sector model to evaluate the BSE impacts on the beef and live cattle industry in Canada including the impacts from BSE-related border closures from other countries to Canadian beef and live cattle and the impacts of BSE risk perception changes from Canadian consumers and cow-calf producers.

The results for each objective will be summarized. The limitations of applying predictive difference and state-space approaches to track risk perceptions are also discussed. Some recommendations for further work based on this thesis will be explored.

7.2 Objective 1-Results

The first objective in this thesis is to construct and estimate a consumer demand model to examine the BSE impacts, study the evolution of risk perceptions about BSE and quantify the effect of media coverage on BSE risk perceptions of beef consumers in Canada. The behavioural changes of Canadian consumers are tracked by structural break tests.

The consumer model in this thesis is constructed as a two-stage demand system with the first stage as a total meat expenditure function in a double-log functional form and the second stage as expenditure share function for each type of meat derived from a Translog indirect utility function. Various BSE information indices are constructed to reflect both the quantity and quality aspects of media information, including gross media index, source credibility media indices and media subject indices. These media information indices are employed in the construction of risk perception equations based on sociological theories including the Social Amplification of Risk Framework (SARF) and the Prospective Reference Theory (PRT). Two approaches are applied to track consumer risk perceptions about BSE: the predictive difference approach and the state-space approach. The predictive difference approach makes use of the difference between two predictions (one based on the pre-risky-event period and the other based on the post-risky-event period or the entire period) from a demand model to approximate risk perception deviations from the bench mark risk perception before the risky event. The state-space approach, on the other hand, estimates the consumer risk perception equation and the consumer demand system jointly by a state-space functional form through Bayesian methods.

Both parametric and non-parametric structural break tests are employed for the BSE-related structural break in consumer behaviour based on time series data and Nielsen Homescan™ household data. The possible structural break points selected include years 2003 to 2006 based on annual Nielsen Homescan™ household data and the first quarter of 1992 (the first case of BSE found in Canada), the first quarter of 1996 (the announcement of possible relationship between BSE and human vCJD), the second quarter of 2003 (the first North American BSE-infected cow was found in Canada), the first quarter of 2004 (one BSE-infected cow was found in the U.S.), the first quarter of 2005 (2 BSE-infected cows were found in Canada) and the third quarter of 2006 (3 BSE-infected cows were found in Canada) based on time series data. Structural breaks are identified in consumer demand system by time series data in the first quarter, 1994 , the first quarter, 1996, the second quarter, 2003, the first quarter, 2004, the first quarter, 2005 and the third quarter, 2006. Structural breaks are also identified in consumer demand system by annual group-wise Nielsen Homescan™ panel data in 2003, 2004 and 2006. Therefore, the first case of BSE found in Canada in 1992 and the announcement of a relationship between BSE and human vCJD in 1996 have already imposed a significant impact on Canadian meat demand prior to any domestic animals with BSE found. The discovery of the first domestic BSE-infected cow in 2003 and the following cases during 2004-2006 further altered consumer preferences about meat eating. The non-parametric structural break tests based on group-wise household panel data from 2002 to 2007 further suggested the second quarter of 2003, the first quarter of 2004 and the third quarter of 2006 presented higher magnitudes of structural changes than the first quarter of 2005.

Both the predictive difference approach and state-space approach based on time series data and group-wise Nielsen Homescan™ household panel data provide empirical support for SARF, suggesting that Canadian consumers' risk perceptions about BSE are amplified by both the quantity and quality of media information about BSE. The PRT is also supported by group-wise Nielsen Homescan™ household panel data. Both the time series data and group-wise Nielsen Homescan™ household panel data revealed a negative impact of risk perceptions on beef demand and a positive impact of risk perceptions on the demand of some other meats.

In terms of different consumer groups, gross media information about BSE plays an amplification role in BSE risk perceptions for group 3 ("somewhat concerned group") and group 4 ("report no beef-eating group") while the gross BSE information plays an attenuation role in BSE risk perceptions for group 1 ("confident group") and group 2 ("neutral group"). This result implies that consumers have certain reference points in their SARF process based on their risk attitudes. The consumers who worry about beef safety will have increasing risk perceptions about BSE after receiving BSE-related information while consumers who believe that eating beef is safe may perceive less risk even after receiving BSE-related information.

For different groups, the media indices play different roles in affecting risk perceptions. The media information addressing government amplifies risk perceptions about BSE for group 3 and group 4 but ameliorates risk perceptions about BSE for group 1 and group 2. The media information addressing scientists amplifies risk perceptions about BSE for group 1 and group 2 but ameliorates risk perceptions about BSE for group 3 and group 4. These results suggests that consumers who trust beef safety will also trust government information about BSE but doubt scientific information about BSE while consumers who distrust beef safety will distrust government information and rely on scientific information about BSE. The BSE information about BSE-affected producers amplifies risk perceptions for group 3 and group 4 but attenuates risk perceptions for group 1 and group 2, indicating "Sympathy" or "Altruism" for BSE affected producers due to BSE outbreak appears in consumers who trust beef safety.

The time trend variable to account for self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998) has a negative impact on risk perceptions of group 1 and group 2 but a positive impact on risk perceptions of group 3 and group 4, implying that consumers who trust beef safety will adjust their risk perceptions of BSE back to their baseline or reference risk level while consumers who distrust beef safety will increase their risk perceptions about BSE over time. In all groups, the elasticities of beef demand with respect to risk perceptions about BSE are negative while those of other meat demands are positive, suggesting a substitution of other meats for beef due to BSE outbreak. Further, group 3 (“somewhat concerned group”) has the highest risk perception elasticity among the four groups.

In summary, the first objective of this thesis is realized by applying SARF and PRT into consumer demand analysis to estimate consumer risk perceptions empirically and to evaluate the impacts of various media indices on consumer risk perceptions about BSE. A theoretical and empirical framework to identify the connections between information and consumer risk perceptions and between consumer risk perceptions and consumer decision-making has been provided, a framework aiming to explaining the impacts of information on the demand model. The elasticities of consumer meat demand with respect to risk perceptions about BSE are further analyzed and a negative impact of risk perceptions on beef demand and a positive impact of risk perceptions on the demand of some other meats are identified.

7.3 Objective 2-Results

The second objective of this thesis is to construct and estimate a cow-calf producer model including beef cow inventory equations and slaughter cow supply equations to examine the BSE impacts, study the evolution of producers’ risk perceptions about BSE and quantify the effects of media coverage on BSE risk perceptions of cow-calf producers in Canada. Structural breaks due to BSE are also tested for, based on the cow-calf producer model.

The producer model including beef cow inventory equation and slaughter cow supply equation is derived from Jarvis (1974) and incorporates price risk (Holt and Chavas, 2002). Similar to the consumer model, BSE information indices are constructed to reflect both the quantity and quality aspects of media information, including gross media index, source credibility media indices and media subject indices. These media information indices are employed in the construction of producer risk perception equations based on SARF and PRT. Predictive difference approach and state-space approach are applied to estimate producer risk perceptions. The basic behavioural equations for producers are the beef cow inventory equations, which are used to approximate producer risk perceptions. However, only reliable annual beef cow inventory data are available and don't provide enough observations to estimate the risk perception equations. As an alternative, the slaughter cow supply equation is used to track cow-calf producers' risk perception changes.

SARF and PRT are supported by both the time series data for Western and Eastern Canada and the panel data of cow-calf sectors in four regions in Canada including Alberta, B.C./Manitoba/Saskatchewan, Ontario, Quebec/Atlantic provinces, suggesting that cow-calf producers' risk perceptions about BSE are affected by both the quantity and quality of BSE information and producers adjust their risk perceptions about BSE using a Bayesian updating procedure.

The estimation of a risk perception equation also reveals different impacts of various media information indices for producers. For example, the gross media information about BSE and the BSE information addressing scientists play attenuation roles in producers' risk perceptions while the BSE information addressing government plays an amplification role in producers' risk perceptions, implying distrust of government by cow-calf producers and trust in scientists. The panel data model also revealed certain impacts of regional specific factors in risk perceptions about BSE but the differences among the regional factors are small, suggesting that the baseline risks across regions are quite similar. The time trend to account for self-adjustment of risk perceptions over time (Kask and Maani, 1992; Liu et al., 1998) has a significantly positive role in risk perceptions, implying cow-calf producers had enlarged risk perceptions about BSE over time. This has been further proved by the measures of increasing risk perceptions in all regions.

In summary, the second objective of this thesis is realized by applying SARF and PRT in producer analysis to estimate producer risk perceptions empirically and to evaluate the impacts of various media indices on producer risk perceptions about BSE. The elasticities of producer slaughter cow supplies with respect to risk perceptions about BSE are further analyzed and a positive impact of producer risk perceptions about BSE on slaughter cow supplies is identified.

7.4 Objective 3-Results

The third objective of this thesis is to develop a beef sector model to evaluate the BSE impacts on the beef and live cattle industry in Canada. This includes examining the impacts from BSE-related border closures from other countries to Canadian beef and live cattle and the impacts of BSE risk perception changes from Canadian consumers and cow-calf producers.

A synthetic model for the North American beef sector is simulated under four scenarios about BSE-related border closures to Canadian beef and live cattle, including a baseline scenario, a scenario restricting cattle trade between Canada and the U.S. to zero, a scenario restricting cattle trade between Canada and the U.S. to zero and limiting beef trade between Canada and the U.S. to half of the original, and a scenario restricting the beef trade between Canada and the rest of the world to zero. As shown in the summary of North American beef sector model, the border closure by the U.S. to Canadian live cattle and reduction of the original Canadian beef export to half results in a significant loss for Canadian beef and live cattle sales as compared to the border closure by the U.S. to Canadian live cattle only. This suggests that the restrictions for beef export have a larger negative impact to Canadian beef sector as compared to the border closure to live cattle only. Beef and live cattle trade between Canada and the U.S. is more important than the beef trade between Canada and the ROW.

Based on the synthetic model for the North American beef sector, the impacts of risk perceptions about BSE are simulated. It has been shown that risk perceptions about BSE have led to a decrease in beef demand and beef retail prices, slaughter cattle prices and slaughter cattle demand in Canada. An increase in risk perceptions about BSE led to losses in both beef sales revenue and slaughter steer/heifer sales revenue in Canada. The losses in beef sales revenue in Canada due to the increases in risk perceptions about BSE can be as large as

4.4%. The losses in slaughter steer/heifer sales revenue can be as large as 6% in Western Canada and 5.2% in Eastern Canada. The losses in slaughter cow/bull sales revenue can be as large as 5.6% in Western Canada and 4% in Eastern Canada.

In summary, the third objective of this thesis is realized by evaluating a synthetic model for the North American beef sector under different scenarios of BSE-related border closures from the U.S. and the ROW to Canadian live cattle and beef products. The impacts of changes in risk perceptions of Canadian consumers and producers on the North American beef sector are assessed. The magnitude of the impacts of SARF in the Canadian beef sector is empirically measured and information is provided for policy makers about how risk perceptions related to BSE have changed the North American beef sector.

7.5 Policy Implications

The policy implications of this thesis are multifaceted. First, there were changes in consumer and producer risk perceptions due to BSE outbreaks and these changes have altered consumers' and producers' behaviour. Those changes increased the losses in the Canadian beef sector. The fact that changing risk perceptions about BSE, only measured for Canadian consumers and cow-calf producers, in the North American beef sector, can affect beef revenues by as much as 4.4% provides evidence that behavioural changes also need to be accounted for by industry and policy makers in their reactions to any animal disease outbreak. In spite of the fact that both federal and provincial governments made significant payouts to producers to alleviate some of the losses they faced while borders remained closed to beef and cattle exports, cow-calf producer concerns about the security of their industry in the future did not disappear. For example, cow-calf producers believed that processors got more money directly from the government or indirectly by manipulating market prices and felt that government should take measures to prevent processors from manipulating market prices (Bogdan, 2008). The reductions in income led to high stress levels for cow-calf producers and even divorce and suicide for some producers (Broadway, 2008). Other issues that require government's intervention include limited slaughter capacity and less bargaining power of cow-calf producers versus packing plants. The design of future support programs should consider market structural issues in terms of who should receive pay-outs. Closed borders for live cattle exports, while beef from certain animals could flow freely, may have created a situation of surplus cattle in Canada, depressing feeder calf prices for a longer period of time than fattened steer and heifer prices, for example. Trickle down effects may not work in situations where there are impediments to trade at one level of the market. Specialized risk communication materials for the different players within an industry like the beef sector may be necessary, as well as specialized support programs.

Many news articles, shortly after the BSE crisis hit (Cape Breton Post, 2003; Chatham Daily News, 2003; Broadcast News, 2003; Statistics Canada, 2004b) reported that Canadian consumers had bucked the international trend and actually increased their beef consumption as opposed to reducing it after May 2003. This analysis was predicated on looking at aggregate disappearance of beef in the country. There are some interesting aspects to this. First beef prices did fall within the country (particularly ground beef prices) and it is possible that consumers responded more to the price declines than to their increased concerns about BSE (the aggregate beef own-price elasticities estimated in this study ranged from -0.45 to -0.88, which are larger than the aggregate risk perception elasticities which ranged from -0.001 to -0.22).

Second, the results of this thesis show that there was significant heterogeneity across Canadian consumers in terms of their responses. Within a sample of Canadian consumers who participate in the Neilsen Homescan™ panel, a small percentage stopped eating beef in the summer of 2003 (6%), another group became more concerned about BSE after the second and third cows were found and changed their consumption and others maintained, and in the short term increased, their beef consumption. Some consumers are gone from the beef market making the market somewhat thinner than it was previously and a little more fragile in the face of another event such as the BSE crisis. Although the industry took on a large advertising campaign domestically in 2003 and 2004, that effort has diminished again ($2.04 million in 2003, $1.81 million in 2004 and $0.90 million in 2008 and 1.28 million in 2009) (Alberta Beef Producers, 2003; 2004; 2008; 2009). It is important that the industry not take Canadian consumers for granted since risk perceptions were heightened by the BSE events which continue to unfold and continue to affect beef purchases. Co-promoting the quality and safety of Canadian beef by government and industry could be an important step in maintaining a strong Canadian consumer beef demand. At the current time, beef's share of total meat expenditure continues to decline. Industry and government need to seriously consider the possibilities of developing traceability tools from farm to final consumers and informing consumers about on farm and industry food safety programs/guarantees. These types of programs may rebuild confidence.

Third, the Canadian beef sector was affected by border closures at two levels of the market – live cattle and beef. Although the beef from animals younger than 30 months became free to flow to the US by September 2003, the industry was negatively affected by continuing live cattle trade barriers and beef trade barriers from other countries. One strategy (Fairbairn and Gustafson, 2005) attempted by the government at the time was to encourage the development of more domestic slaughter capacity, focusing on the development of co-operative producer member firms. Although there was a need for slaughter capacity at the time there were also seriously depleted financial resources within the beef production sector. The susceptibility of the industry to trade barriers at either or both market levels remains high. In the longer term industry and both levels of government may want to consider how they might support the development of more domestic slaughter capacity. Although currently, exchange rates and COOL are also negatively affecting the industry, returns may be higher in the future and in a period of higher returns, cow-calf producers and independent feedlots may be able to consider investing in specialized niche market processing facilities in Canada. Providing support of this sort to industry might alleviate some of the risk perceptions held in the cow-calf sector. Further research should address those same concerns to see if the ones held by feedlot operators and the purebred sector are higher or lower than those felt by cow-calf operators.

Fourth, the results from this study can be used by industry decision-makers to help understand some of the more subtle implications of an event such as BSE. Given the measures of changes in beef consumers' and producers' risk perceptions generated in this study, government and industry should have increased awareness of these potential changes for any similar animal disease outbreaks. Understanding the importance of directly addressing the concerns of producers and consumers, even with limited short term evidence of reaction by these groups, can help reduce the long term negative repercussions for industry.

7.6 Limitations of Approximating Risk Perceptions through Market Behaviour

Two approaches are applied in this thesis to track risk perception changes of consumers and cow-calf producers including the predictive difference approach and the state-space approach. These two approaches are both based on observed market behaviour. As discussed in the literature review, these approaches can avoid the issues of the designed survey or experiment approach such as the extent of reliability and validity, and a high cost of having continuous surveys or experiments to track risk perception evolution. Further, the two approaches can obtain the parameters within the risk perception equation and the parameters in behavioural models of consumers or producers at the same time, making it possible to evaluate the impacts of factors unobservable but updating over time such as risk perceptions about BSE.

However, these approaches can't be applied to elicit people's risk perceptions directly like designed surveys or experiments and certain estimation procedures must be employed for these approaches. For example, BSE risk perceptions are approximated by a behavioural response approach through the differences of two predictions: one based on whole time period and the other based on pre-BSE period. Because the predictions are already based on the behavioural models of consumers or producers, it is not possible to identify the parameters of risk perceptions in behavioural models. The state-space approach, on the other hand, can be used to identify the parameters of risk perceptions in behavioural models. However, more complexity in estimation is added in a state-space model and extra constraints for parameters within risk perception equations must be imposed to gain identification. Given these issues, the two approaches represent some initial work to apply SARF derived from sociological and psychological studies about risk perceptions into economic models of consumers and cow-calf producers.

7.7 Future Directions

As discussed above, the approaches applied in this thesis are not without problems. Some improvement from these approaches might be used to solve these problems. First, a combination of data from designed surveys or experiments and data from real market behaviour may be used to solve the identification problem and evaluate the impacts of risk perceptions in market behaviour of consumers and producers. In the designed surveys or experiments, certain set of questions can be used to elicit consumers' or producers' risk perception directly. On-going surveys or experiments can be applied to track the dynamics of risk perceptions over time. The risk perceptions collected from the surveys or experiments can then be incorporated as a variable in behaviour models of these consumers or producers based on their real market data. However, such an improvement also comes with a high cost of collecting both the experiment /survey data and the real market data over time.

Second, omitted variables can be incorporated into the consumer or farmer behaviour models to decrease the heteroskedasticity and endogeneity, if any exists. These variables may affect the predictive differences in consumer and cow-calf producer models. When estimating the risk perceptions, the omitted variables may create specification errors and decrease the precision of risk perception approximations. For consumers, the food safety information, health information, advertising, store choices may be included and for producers, technical change and demographic profiles may be incorporated.

Third, a more detailed beef sector model can be estimated or simulated to evaluate the BSE impacts in various sectors within Canadian beef supply chain. It is worth noting that in the Canadian model risk perception changes were only modelled for consumers and cow-calf producers. The reactions of Canadian consumers are simulated by aggregated time series data, which assumes the conditions of aggregation among Canadian consumers are satisfied and ignores the difference of demographic profiles of different Canadian households. An improvement for simulating consumer behaviour is to use the estimates from models based on clustered household data. By matching the demographic profiles of households in each cluster to those in Canada, the Canadian population can be clustered into different groups and the parameter estimates from clustered households can be used to simulate the behaviour of the Canadian population by group. Such an approach will provide results that are more precise than those based on aggregate time series data by recognizing the differences related to demographics and differences in meat purchase behaviour of Canadian households from different groups.

By holding cows, feeder calves that provide all of the steers and heifers for slaughter and export in later periods are produced. There are other participants in the beef sector – feedlot operators and meat processors to name only two. The owners in these sectors may have different risk perceptions about BSE and have different reactions, which could add more volatility to beef supply and in turn, affect the market equilibrium in either live cattle or beef products. Given sufficient datasets, the empirical analysis of the intermediate sectors could alsobe done and provide a more detailed simulation of BSE impacts across the entire Canadian beef supply chain.

It is also noted that the US model used in simulation in this research does not allow for any changes in risk perceptions by any agents in the U.S. consumers, cow-calf producers, feedlot operators or meat processors. Given the dominant nature of the U.S. market in North America any changes in risk perceptions by agents in the U.S. might have impacts in Canada that are as big or bigger than the impacts of changes in risk perceptions of domestic cow-calf producers and consumers. Further research is necessary to estimate whether the U.S. market has been affected by changes in American agent risk perceptions as well.

Fourth, other factors such as changes in exchange rates and weather may also have impacts on cow-calf producer risk perceptions. These effects can be empirically evaluated through different simulation scenarios and compared to the effects of BSE media coverage. As well, further examination of the role of government payments may be more explicitly incorporated into the simulation model to evaluate the impacts of government payments on cow-calf producer risk perception changes. For example, government income stabilization programs can reduce the variability in prices or revenues and decrease producer risk perceptions about cow-calf operations.

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Appendix A

The news articles are collected from the Canadian newspapers, magazines and broadcast news (English media) saved in Factiva, CBCA Business, CBCA Current Events, CBCA Reference, ProQuest Newspapers databases. These newspapers, magazines, broadcast news are:

Broadcast News, Lethbridge Herald, financial post, Nouvelles Tele-Radio, Country Canada - CBC Television, Women's Health Matters, Geriatrics Today, Digital Marketing, Queen's Quarterly, Informal Logic, Saturday Report - CBC Television, The Globe and Mail (Index-only), The National - CBC Television, The Report Newsmagazine (Alberta Edition), Outdoor Canada [Hunting], Cambridge Reporter, Catholic New Times, Investor's Digest of Canada, Econoscope, Canadian Journal of Dietetic Practice and Research, Dundas Star News, Waterloo Chronicle, The East York Mirror, Business in Vancouver, The York Guardian, Food in Canada: Our Annual Top 100, Burnaby Now, Canadian HR Reporter, S S G M, Service Station & Garage Management, Listowel Banner, Ancaster News, Record New, Canadian Medical Association. Journal, Toronto Life, Electrical Business, CIO Governments' Review, The Scarborough Mirror, WellnessOptions, Journal of Agricultural and Environmental Ethics, Canadian Wildlife, Atlantic Report, The Mirror. The Midland - Penetanguishene Mirror, Orillia Today. Orillia Today, The Advance. Barrie - Advance, Oakville Beaver, Flamborough Review, Delta Optimist, Richmond News, The Brampton Guardian, Etobicoke Guardian, Genome, Canadian Transportation Logistics, PrintAction, Canadian Jewish News, Ottawa Business Journal, Western Living (Vancouver Edition)., Natural Life, Dogs in Canada, Backgrounder - C. D. Howe Institute, Marketing Magazine, Ontario Out of Doors, On - Site, National Post Business, Materials Management and Distribution, Research Money, Mississauga News, cabe.ca, Journal of Commerce, Health Reports, Sterling News Service British, The Northern Sentinel, Canadian Living, Canadian Journal of Public Health, Canadian Journal of Earth Sciences, Adbusters, The Agassiz - Harrison Observer, International Journal, The Midland - Penetanguishene Mirror, The Journal, Regina Sun, Harbour City Star, Parksville - Qualicum News, Machinery &

Equipment, Now, Hanover Post, YCM, Your Convenience Manager, United Church Observer, The Presbyterian Record, Outdoor Canada, Alberta Views, The Liberal, ComputerWorld, Canadian Mennonite, Question Period - CTV Television, Langley Advance, Omineca Express, The Caledonia Courier, Canadian Economic Observer, Canadian Association of Radiologists Journal, Cowichan News Leader, Maple Ridge, Pitt Meadows Times, Courier - Islander, Times, Colborne Chronicle, National, Uxbridge Times - Journal, Herald, The Post, North Island Weekender, Eagle Valley News, Flamborough Post, The North Shore Outlook, Midweek Banner, The Kootenay Advertiser, Maclean's, Markham Economist & Sun, Technology in Government, Oilweek, Media, HighGrader Magazine, Saanich News, Oak Bay News, The Sooke Mirror, Business Examiner (North Island Ed.)., Hardware & Home Centre Magazine, Briar Patch, Northumberland News, This Week, Canadian Biotech News, Clinical and Investigative Medicine, CCPA Monitor, Avenue, The News : Esquimalt, Revelstoke Times Review, The Collingwood Connection, Our Times, Grocer Today, Time (Canadian Edition)., The Leader, Embassy Ottawa, Salmon Arm Observer, Marketing, Country Guide Ontario, Broadcaster, Mission City Record, Lindsay This Week, The Canadian Champion, The Independent & Free Press, Cowichan Valley Citizen, Langley Times, Nova Scotia Business Journal, Canadian Commerce & Industry, Peterborough This Week, Niagara This Week, The News Advertiser, Canadian Parliamentary Review, Policy Options, Northern Aquaculture, Business in Calgary, Hamilton News, Mountain Edition, The Hill Times, Daily Commercial News and Construction Record, Northern Daily News, The Merritt Herald, WestEnder, Commentary - C.D. Howe Institute, Plant, Similkameen Spotlight, Saskatoon Sun, Alberta Venture, The Times, Dunnville Chronicle, The Tri City News, Kelowna Capital News, Coquitlam Now New, Solid Waste & Recycling, Houston Today, Chatelaine (English Edition)., The Interior News, Vancouver Courier, Stoney Creek News, National Post (Index-only), Western Producer, Saskbusiness, Canadian Journal of Agricultural Economics, Canadian Grocer, Nanaimo News Bulletin, Tribune, Nelson Daily News, St. Mary's Journal - Argus, Quesnel Cariboo Observer, Castlegar News, The Lake Windermere Valley Echo, Free Press, Enterprise - Bulletin, Daily Townsman, Daily Bulletin, Barrie - Advance, Era - Banner, CTV News - CTV Television, Orillia Today, Telegram, Kingston Whig - Standard, Global News Transcripts, Canada AM - CTV Television, Nanaimo Daily News, The Prince George Free Press, The Tribune, North Shore News, Record, Penticton Western News, New Hamburg Independent, Lindsay Daily Post, The Aldergrove Star, Trail Times, The Morning Star, North Thompson Journal, Medical Post, The Record, The News, Prince Albert Daily Herald, Packet and Times, Standard, 100 Mile House Free Press, Alberni Valley Times, The Standard, The Province, North Bay Nugget, Evening Guide, Cobourg Daily Star, Cape Breton Post Cape, The Spectator, Food in Canada, Toronto Star, Lakes District News, Expositor, Western Star, Prince George Citizen, Peace River Block Daily News, Niagara Falls Review, Guardian, Daily Press, Sault Star, Daily Mercury, Alaska Highway News, The Chilliwack Progress, Examiner, The Vancouver Sun, Moose Jaw Times Herald, Kamloops Daily News, Evening News, Chilliwack Times, Abbotsford Times, Standard - Freeholder, Peterborough Examiner, Star - Phoenix, Western Standard, Pembroke Observer, Leader Post, The Courtenay Comox Valley Record, CCNMatthews Newswire, Canadian Press NewsWire, Times - Colonist, The Windsor Star, The Ottawa Citizen, The Intelligencer, Observer, Daily News, Chatham Daily News, CanWest News Don, Kamloops This Week, Countdown, Sun Times, Journal - Pioneer, Whitehorse Star, The Gazette, Sudbury Star, Canadian Dimension, Solid Waste, Canada & the World Backgrounder, Canadian Public Policy, Shareowner, Mike Duffy Live, Journal of Comparative Family Studies, Manitoba Business, OH&S Canada, Centre, Ottawa Citizen, Edmonton Journal, Vancouver Sun, Montreal Gazette, The Globe and Mail (Breaking News), Truck News, eSource Canada Business News Network, New Technology Magazine, Computing Canada, Canadian Literature, CA Magazine, Relations Industrielles, Canadian Underwriter, The Independent - London, Bank of Montreal: The Weekly, Strategy, Adnews Online, The Christian Science Monitor, KidScreen, Global Outlook, Playback, Canadian Insurance, Canadian Chemical News, Benefits Canada, The Daily Oil Bulletin, CMA

Management, Northern Ontario Business, Foodservice & Hospitality, Bank of Montreal International Economic Review, Alternatives Journal, Canadian Business, Time (Canadian Edition), PROFIT, The Cambridge Reporter, Question Period, Breaking News from globeandmail.com, Canadian Geographic, BC Business, Canadian Geographer, Canada AM, CCNMatthews (Canada), Bank of Canada Review, CCNMatthews, CTV News - PM, Canada Stockwatch, Market News International, The Toronto Star, Mosaic (Winnipeg), Calgary Herald, Canada NewsWire, National Post, Resource News International, Winnipeg Free Press, Guelph Mercury, The Globe and Mail, Market News Publishing, The Hamilton Spectator, Kitchener-Waterloo Record, The Canadian Press.

Appendix B

Consumer Time Series Data

1. Stability Test of Consumer Time Series Data

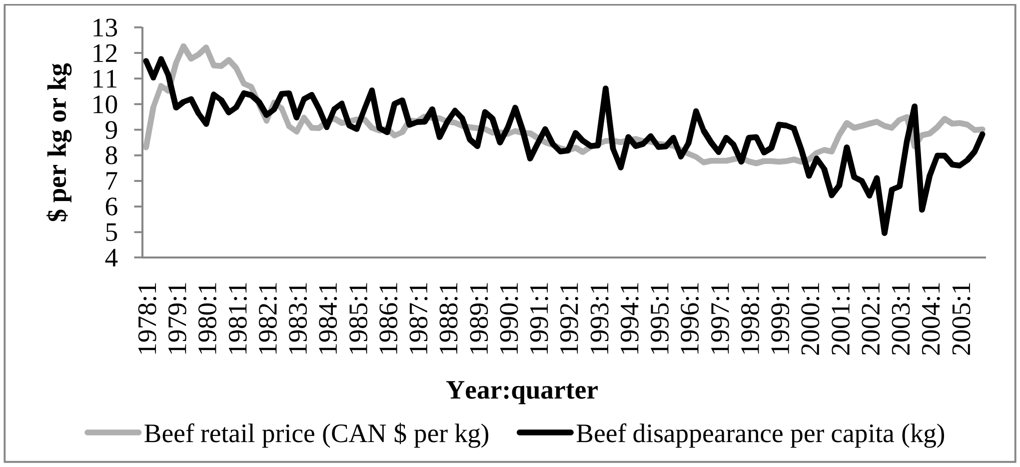
The consumer time series data is tested for long run stability as shown in the following table:

Variables	P-value		
	Augmented Weighted Symmetric tests	Augmented Dickey-Fuller tests	Phillips-Perron variation of the Dickey-Fuller test
Total meat expenditure per capita (CAN $)	0.931	0.981	0.158
Per capita disposable income (CAN $)	0.290	0.466	0.488
Beef expenditure share	0.103	0.621	0.001
Pork expenditure share	0.001	0.055	0.001
Chicken expenditure share	0.016	0.102	0.001
Turkey expenditure share	0.144	0.243	0.001
Beef disappearance per capita (kg)	0.039	0.138	0.001
Pork disappearance per capita (kg)	0.032	0.953	0.003
Chicken disappearance per capita (kg)	0.013	0.066	0.001
Turkey disappearance per capita (kg)	0.352	0.553	0.001
Beef retail price (CAN $ per kg)	0.079	0.280	0.129
Pork retail price (CAN $ per kg)	0.096	0.074	0.033
Chicken retail price (CAN $ per kg)	0.770	0.873	0.064
Turkey retail price (CAN $ per kg)	0.885	0.910	0.056
BSE media index	0.033	0.410	0.011
BSE information from national media	0.018	0.870	0.023
BSE information from local media	0.050	0.709	0.006
BSE information from print media	0.032	0.412	0.011
BSE information addressing government	0.520	1.000	0.004
BSE information addressing scientists	0.797	1.000	0.001
BSE information addressing producers	0.475	0.093	0.014
BSE information addressing BSE affected producers	0.415	0.913	0.008

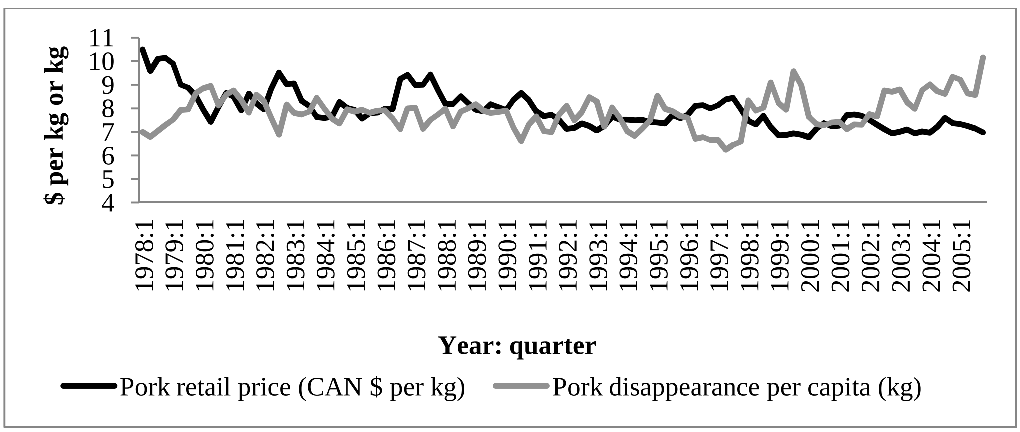
2. Historical Trends of Individual Meat Disappearance and Prices

The prices and disappearance for individual meat are shown in the following graphs:

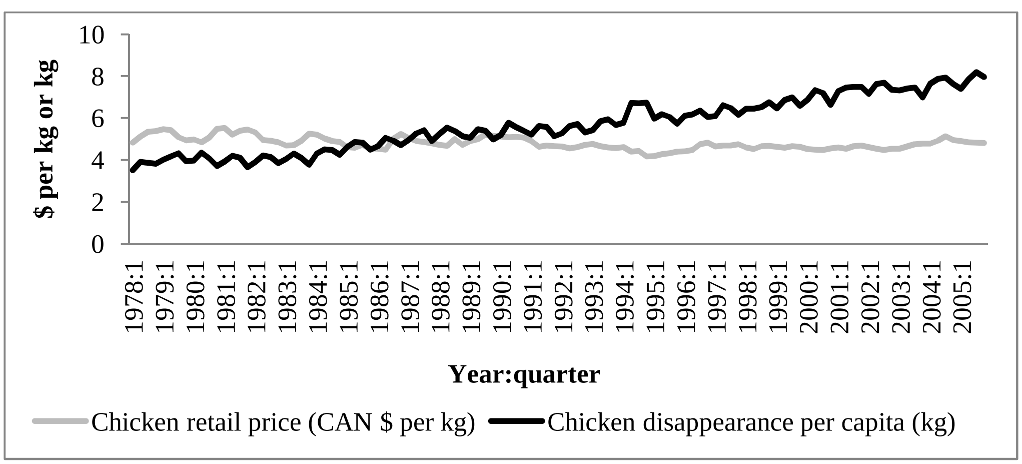
Beef Prices and Disappearance, 1978:1-2005:4



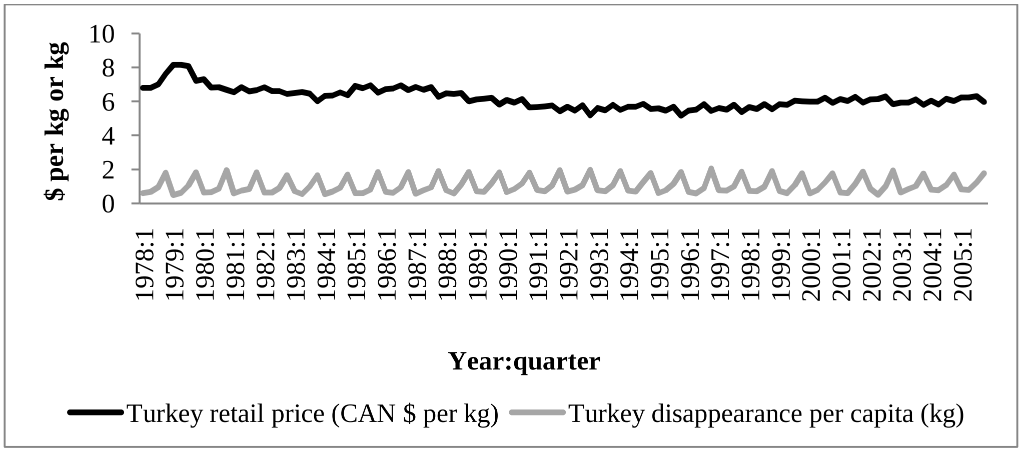
Pork Prices and Disappearance, 1978:1-2005:4



Chicken Prices and Disappearance, 1978:1-2005:4



Turkey Prices and Disappearance, 1978:1-2005:4



Household Panel Data Collection and Generation Procedure

1. **Demographics of Canadian Households**

All the data about Canadian household demographics are based on 2006 Census of Canada (Statistics Canada, 2006). The data about household size and regional distributions in Canada are collected from 2006 Census of Population. Data about age and presence of children are collected from Catalogue Number 97-553-XCB2006022, Age Groups of Children at Home. Income data are collected from Catalogue Number 97-563-XCB2006045, Household Income Groups. Data about language are from Catalogue Number 97-555-XCB2006030, First Official Language Spoken.

2. **Meat Expenditure and Price Generation for ACNielsen Homescan™ Panel Data**

The expenditure for different types of meats is generated through the meat type codes within AC Nielsen Homescan™ panel data. Specifically, there are 48 types of products, including bacon, bacon beef, bacon turkey, beef, beef/pork, beef/pork/chicken, beef/shrimp, bison, bison/pork, boar, buffalo, calves, capon, chicken, chicken/bacon, chicken/pork, cornish hens, duck, elk, emu, fowl, frog, goat, goose, guinea fowl, ham, horse, lamb, not applicable, ostrich, partridge, pheasant, pork, pork/lamb, pork/veal, poultry, quail, rabbit, turkey, turkey/pork, turkey/veal, veal, veal/pork/beef, venison, beef/bacon, assorted, seafood, all types.

The beef expenditure includes the expenditure for beef and expenditure for veal due to the fact that they are major beef purchase categories that account for 35.35% of meat purchases in whole AC Nielsen Homescan**TM** panel data and account for 23.58% of meat purchases in sub-sample of AC Nielsen Homescan**TM** panel data based on consumer survey. The products with beef, veal and other meats mixed or processed beef such as beef/pork, beef/pork/chicken, beef/shrimp, veal/pork/beef, beef/bacon, turkey/veal, pork/veal and bacon beef are not included in beef expenditure because they account for only 0.8% of meat purchases in both whole AC Nielsen Homescan**TM** panel data and sub-sample of AC Nielsen Homescan**TM** panel data based on consumer survey. Further, it is hard to determine the beef percentages in the mixed meat types. In pork, chicken and turkey expenditure, the considered meat categories are "pork", "chicken" and "turkey" respectively. The mixed meat types related to pork, chicken and turkey such as beef/pork, beef/pork/chicken, veal/pork/beef, chicken/pork, bison/pork, beef/pork/chicken, pork/veal, turkey/pork, pork/lamb, chicken/bacon, turkey/veal are not included for the same reason as the mixed meat types related to beef.

Another issue is the processing of UPC coded data and non-UPC coded data. The non-UPC coded data account for the major part of the whole AC Nielsen Homescan**TM** panel data and the sub-sample of the AC Nielsen Homescan**TM** panel data based on consumer survey. In the whole sample and the sub-sample, non-UPC coded data account for about 85% and 86% respectively in all observations. In UPC-coded data within the whole sample and the sub-sample, chicken purchase data account for 35% and 34% respectively in all observations, seafood 27% and 28%, all types (the meat or product types are not identifiable) 37% and 37%. The purchase data of beef, pork, turkey only account for 1.4% and 1.3% in UPC-coded data within the whole sample and the sub-sample respectively. Given these facts and for simplicity, the UPC-coded data are coded in the same way as the non-UPC coded data, including beef, pork, chicken, turkey, seafood and all types.

The third issue concerns the generation of regional retail prices of different types of meats. There is no price information in non-UPC coded data. In UPC-coded data, prices may be computed given the unit code is pound or kilogram but not computable if the unit code is “unit” because there is no other information about the measure of the “unit”. The UPC-coded beef products have 71% with unit code as” unit”, UPC-coded pork products 89% and UPC-coded turkey products 82%. The UPC-coded chicken products have 44% with unit code as “unit” and UPC-coded seafood products 1%. Considering the small percentage of UPC-coded meat products in total meat purchases and the large percentage of “unit” coding in UPC-coded beef, pork and turkey products, the prices for UPC-coded beef, pork and turkey products are rendered the same as those for non-UPC coded beef, pork and turkey products. However, because of the relatively small percentages of “unit” coding in UPC-coded chicken and seafood products, the prices of UPC-coded chicken and seafood products are generated differently. If the unit coding of UPC-coded chicken products is “unit”, the chicken prices are rendered the same as non-UPC coded chicken products while if the unit coding of UPC-coded chicken products are pounds or kilograms, the chicken prices are computed through dividing the chicken expenditure by units. The seafood purchases only appear in UPC-coded products and the prices of seafood are computed through dividing the seafood expenditure by units if the unit coding are pounds or kilograms. If the unit coding of seafood is “unit”, the seafood prices is imputed as averages of seafood prices in different regions and different time periods in sample data given the fact that most of the seafood prices can be computed in sample and the regional retail prices of seafood are not available from Statistics Canada or Economic and Market Information (EMI) section within Agriculture and Agri-food Canada (AAFC). In terms of retail prices of non-UPC coded products, the prices are either found in Statistics Canada or EMI/AAFC. Specifically, the regional retail prices of turkey by different weights and cuts are available from EMI/AAFC, Table 031: average monthly weighted retail poultry prices. The turkey retail prices applied in model estimations are the weighted average prices of turkey above 5 kg (including 5 kg) and under 8 kg fresh because turkey prices in this category have fewer missing observations than those in other categories. The missing data of turkey prices in Western (Eastern) Canada provinces are replaced by the average prices of turkey above 5 kg (including 5 kg) and under 8 kg fresh in Western (Eastern) Canada. The regional retail prices of beef, pork and chicken are not available from statistics Canada or EMI/AAFC and therefore, need to be generated. Because the data of national level retail prices of beef (by different cuts), pork(pork chops) and chicken[62] and the data of national and regional consumer price indices of beef, pork and chicken (Statistics Canada database CANSIM II Table 3260012 and 3260020) are available, the regional retail prices of beef, pork and chicken are generated by following steps. First, the national level retail prices of beef are computed as a weighted average of prices of "roundsteak", "wieners", "sirloinsteak", "primeribroas", "bladeroast", "stewingbeef" and "groundbeef". The weights used are carcass portions of different cuts in steer/heifer slaughtered (round steak, 0.1062, serloin steak, 0.1853, prime rib roast 0.0674, blade roast, 0.1254, stewing beef, 0.204, ground beef, 0.0672) (John, 2007). The national level retail prices of pork are computed as the prices of "porkchops". The national chicken price is available and no need to calculate. The national and regional consumer price index of beef (pork, chicken) is computed as the price index of "Fresh or frozen beef (pork, chicken)". Second, the regional retail prices of beef (pork, chicken) are computed by:

Regional retail prices of beef (pork, chicken) =national retail prices of beef (pork, chicken)* regional consumer price index of beef (pork, chicken)/ national consumer price index of beef (pork, chicken)

3. Missing and Wrong Coding Observations

Several issues exist in Home-Scan panel data. First, missing observations are present in most of the households (there are 16515 households in Home-Scan panel while only 852 households are observed each month). Second, there are 4144 wrong coding expenditure observations given the fact that these observations have units consumed bigger than zero but have expenditure equal to

[62] The regional retail prices for different cuts of chicken products are also available from AAFC webpage Table 031: average monthly weighted retail poultry prices. However, they are not aggregated and may have biases during aggregation. To maintain consistency of data generation, we use the same approach as that of beef and pork to calculate regional prices of chicken.

zero. There are several approaches to deal with missing observations such as replacing by zero or mean values of variables and multiple imputations. For simplicity, the missing records of Home-Scan panel are set to zero with the assumption that if those households are not observed in certain time period, they didn't consume at that time period. The wrong coding expenditure observations are deleted during the analysis because they are comparatively small in whole Home-Scan panel data and only account for 0.1%.

4. **Meat Expenditure, Price and Demographic Variable Aggregation**

The meat expenditure is aggregated by households to monthly, quarterly and yearly observations. The prices of different types of meats are averaged over quarter, year to get the aggregated meat prices. The demographic variables are stable in certain year and therefore, they can be included into the yearly data without any manipulations.

Cow-Calf Producer Data

1. **Beef and Dairy Cow Inventory**

The annual beef or dairy cow inventory data are from Statistics Canada database CANSIM II Table 30032 - Number of cattle, by class and farm type, annually (Head) (CANSIM II, 2006). The data of July inventory cover the period 1931-2008 while the data of January inventory cover the period 1940-2008.

2. **Slaughter Cow Supply**

Cow Slaughtered at Federally/Provincially Inspected Packing Plants

The monthly data of slaughter cow/bull slaughtered were collected from Livestock and Meat Trade Report (weekly publications) from Agriculture and Agri-Food Canada (AAFC, 2008). For the period Nov., 1992 to Dec., 1995 and for the period Jan., 1997 to Dec., 1999, the data of Saskatchewan and Manitoba are merged. For the period Apr.,2001 to Dec., 2008, the data of Quebec and Atlantic Provinces are merged. For the period Jan., 2000 to Dec., 2008, the data of Saskatchewan and Manitoba and B.C. are merged. For the period 1970 to 1979, only federally inspected slaughter is reported.

Cow Export to the U.S.

The quarterly cow export data from 1972 to 1992 were collected from Livestock and Meat Trade Report (weekly publications) from Agriculture and Agri-Food Canada (AAFC, 2008). From 1993 to 2009, the cow export data were requested by Ellen from Statistics Canada (Cows nes, exec dairy, for immediate slaughter, weighing 320 kg or more). Because the export data of cows were not reported in Livestock and Meat Trade Report from 1970 to 1979, the data of exports of grade beef females are used to approximate the cow exports. The data of cow export from 1970 to 1980 were only classified into Western Canada and Eastern Canada. To obtain a provincial level data, the cow export numbers in Western Canada and Eastern Canada were broken into provincial level by the shares of slaughter cow number of the provinces in Western (Eastern) Canada over the slaughter cow number in whole Western (Eastern) Canada. The monthly data of cow export in 1983 were not reported while the annual data of cow export in 1983 was available. Therefore, the quarterly data of cow export were approximated by:

The cow export in ith quarter of 1983=the total number of cow export in 1983 (from annual livestock market review)*(the cow export share in ith quarter of 1984+the cow export share in ith quarter of 1982)/2

3. **Feeder Calf Prices and Slaughter Cow Prices**

The quarterly feeder calf price data were collected from CANSIM II (2006), Livestock and Meat Trade Report (weekly publications). The quarterly feeder calf price data in Western Canada from 1940 to 1990 were collected from CANSIM agricultural division, STC (23-603): average cattle prices / feeder steers, good average prices at Calgary. The quarterly feeder calf price data in Eastern Canada from 1930 to 1990 were collected from CANSIM agricultural division, STC (23-603): average cattle prices / feeder steers, good avg prices at Toronto. The data of quarterly slaughter cow prices in Western Canada from 1948 to 1992 and the quarterly slaughter cow prices in Eastern Canada from 1960 to 1992 were collected by Ellen from CANSIM. The data of quarterly slaughter cow and feeder calf prices in Western and Eastern Canada from 1993 to 2008 were collected from Livestock and Meat Trade Report 1993 to 2008. The provincial level price data were not available in these publications and therefore, the quarterly slaughter cow prices in provinces in Western (Eastern) Canada were represented by the slaughter cow prices in Western (Eastern) Canada. The slaughter cow prices in Eastern Canada from 1948 to 1960 were represented by the prices in Western Canada due to no differentiation between Western and Eastern Canada in terms of price reports at that time period.

4. **Feed Grain Prices**

The quarterly corn prices from 1959 to 2008 were collected by Ellen from CANSIM. The corn prices from 1908 to 1958 were collected from CANSIM SDDS 3401 STC (22-002): Corn for grain/ AV. Farm price per tonne, corn for grain. The data of 1908 to 1958 were annual and converted to quarterly by using the annual numbers as quarterly numbers. The quarterly barley prices from 1963 to 2008 were collected by Ellen from CANSIM. The barley prices from 1908 to 1962 were collected from CANSIM SDDS 3401 STC (22-002): Barley. / AV. Farm price per tonne, barley- ALTA. The data of 1908 to 1962 were annual and converted to quarterly by using the annual numbers as quarterly numbers.

5. **Bank Rates, Producer Subsidy Estimates, Media Information of BSE Available to Canadian Producers**

Monthly bank rate data from 1935 to 2009 were from Statistics Canada (CANSIM II series v122530). The annual producer subsidy estimates from 1979-2008 were collected from OECD.

The media information about BSE from 1990-2008 come from national media including Globe and Mail and National Post and regional media including Western Producer, Country guide, Manitoba Co-operator and Ontario Farmer. Similar to the construction of various media indices in consumer chapter, the national media index and the subject indices about BSE are established. The subject indices of BSE include the BSE information addressing government, scientists and producers.

6. **Stability Test of Producer Time Series Data**

The producer time series data is tested for long run stability as shown in the following table:

Variables	P-value		
	Augmented Weighted Symmetric tests	Augmented Dickey-Fuller tests	Phillips-Perron variation of the Dickey-Fuller tests
Feeder calf price in Western Canada ($/100 lbs)	0.127	0.253	0.159
Cow price in Western Canada ($/100 lbs)	0.377	0.320	0.230
Feeder calf price in Eastern Canada ($/100 lbs)	0.072	0.152	0.094
Cow price in Eastern Canada ($/100 lbs)	0.372	0.327	0.246
Feed grain price in Western Canada ($ per metric tonne)	0.012	0.025	0.038
Feed grain price in Eastern Canada ($ per metric tonne)	0.010	0.016	0.007
Bank rates	0.789	0.236	0.283
Feeder calf price/feed price in Western Canada	0.004	0.012	0.077
Cow price/feed price in Western Canada	0.062	0.139	0.117
Squared standard deviation (SSD) of ratio of slaughter cow price over feed pricea in Western Canada	0.011	0.033	0.000
SSD of ratio of feeder calf price over feed price in Western Canada	0.002	0.005	0.000
Slaughter cow supply lagged one period in Western Canada	0.035	0.080	0.000
Beef and dairy cow inventories in Western Canada (1000 head)	0.922	0.722	0.925
Dairy cow inventories in Western Canada (1000 head)	0.823	0.739	0.841
Feeder calf price/feed price in Eastern Canada	0.001	0.003	0.021
Cow price/feed price in Eastern Canada	0.042	0.134	0.075
SSD of ratio of slaughter cow price over feed pricea in Eastern Canada	0.000	0.000	0.002
SSD of ratio of feeder calf price over feed price in Eastern Canada	0.000	0.000	0.001
Slaughter cow supply lagged one period in Eastern Canada (1000 head)	0.690	0.186	0.000
Beef and dairy cow inventories in Eastern Canada (1000 head)	0.592	0.288	0.487
Dairy cow inventories in Eastern Canada (1000 head)	0.980	0.819	0.934
Producer subsidy estimates ($ per metric tonne)	0.076	0.157	0.071

Appendix C

Table C.1 Estimation of Demand Model Based on Time Series Data and Predictive Difference Approach

Equation	Variable	Parameter Estimate[a]	
		The first quarter, 1978- the first quarter,2003	The first quarter,1978- the fourth quarter, 2005
Beef, pork, chicken, turkey equations	Beef price*chicken price	0.060 (3.970) ***	0.060 (4.080) ***
	Pork price*chicken price	0.040 (3.350) ***	0.040 (2.950) ***
	Chicken price*chicken price	-0.090 (-4.890) ***	-0.100 (-4.650) ***
	Beef price*pork price	0.090 (3.160) ***	0.130 (3.950) ***
	Pork price*pork price	-0.140 (-4.090) ***	-0.180 (-4.510) ***
	Beef price*beef price	-0.160 (-4.510) ***	-0.210 (-5.130) ***
	Beef price*turkey price	0.010 (1.680)	0.010 (1.770)
	Pork price*turkey price	0.010 (1.260)	0.010 (0.920)
	Chicken price*turkey price	-0.010 (-0.810)	-0.010 (-0.800)
	Turkey price*turkey price	-0.020 (-1.710)	-0.010 (-1.490)
Beef equation	Constant	-0.550 (-15.260) ***	-0.520 (-13.850) ***
	Time	0.0020 (8.960) ***	0.002 (6.500) ***
	Lagged beef disappearance	-0.010 (-2.050) *	-0.020 (-30.000) ***
	Quarter 1	-0.050 (-2.070) *	-0.040 (-1.750)
	Quarter 2	-0.070 (-2.980) ***	-0.090 (-3.140) ***
	Quarter 3	-0.0030 (-0.140)	-0.020 (-0.890)
Pork equation	Constant	-0.280 (-8.110) ***	-0.280 (-7.870) ***

	Time	0.001 (0.960)	0.001 (-0.310)
	Lagged pork disappearance	-0.020 (-3.680) ***	-0.030 (-4.250) ***
	Quarter 1	-0.020 (-1.140)	-0.010 (-0.450)
	Quarter 2	0.020 (1.270)	0.030 (1.650)
	Quarter 3	0.030 (1.720)	0.030 (1.750)
Chicken equation	Constant	-0.080 (-5.480) ***	-0.100 (-5.600) ***
	Time	-0.001 (-3.870) ***	-0.001 (-4.500) ***
	Lagged chicken disappearance	-0.010 (-2.290) **	-0.010 (-2.090) *
	Quarter 1	-0.020 (-2.160) *	-0.020 (-1.720)
	Quarter 2	-0.020 (-2.330) **	-0.020 (-2.230) **
	Quarter 3	-0.002 (-0.330)	-0.010 (-0.760)
Turkey equation	Constant	-0.090 (-10.600) ***	-0.100 (-10.470) ***
	Time	0.001 (-1.440)	0.001 (-2.460) ***
	Lagged turkey disappearance	0.010 (1.350)	0.010 (2.240) **
	Quarter 1	0.040 (7.200) ***	0.050 (7.150) ***
	Quarter 2	0.050 (10.570) ***	0.060 (10.580) ***
	Quarter 3	0.040 (9.430) ***	0.040 (9.730) ***
Total Meat expenditure equation	Constant	-0.700 (-0.830)	-2.470 (-3.120) ***
	Quarter 1	-0.040 (-4.900) ***	-0.040 (-4.410) ***
	Quarter 2	-0.010 (-0.930)	-0.010 (-0.580)
	Quarter 3	-0.010	-0.003

		(-0.730)	(0.300)
	Stone price index	0.630 (7.800) ***	0.590 (7.210) ***
	Per capita disposable income	0.360 (3.960) ***	0.530 (5.810) ***
	Lagged meat expenditure	0.240 (3.800) ***	0.280 (4.690) ***
	Time	-0.030 (-2.940) ***	-0.040 (-3.250) ***

a: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels.
b: The dummies for all quarters after the BSE outbreak in the second quarter of 2003 are used initially to track the structural changes of consumer demand due to the insufficient observations to estimate the demand system after BSE outbreak. These dummies are insignificant and removed by likelihood ratio tests to improve the model fit.

Table C.2 Estimation of Demand Model Based on Time Series Data and State-Space Approach

Equation	Variable	Parameter Estimatesb		
		Model 1	Model 2	Model 3
Beef, pork, chicken, turkey equations	Beef price*beef price	0.037 (0.140)	0.023 (0.090)	0.011 (0.040)
	Beef price*pork price	0.019 (0.120)	0.004 (0.030)	0.005 (0.030)
	Beef price*chicken price	0.016 (0.10)	0.035 (0.230)	0.040 (0.260)
	Beef price*turkey price	-0.071 (0.480)	-0.062 (0.400)	-0.055 (0.360)
	Pork price*pork price	0.007 (0.040)	0.026 (0.120)	0.022 (0.100)
	Pork price*chicken price	-0.026 (0.180)	-0.030 (0.190)	-0.027 (0.170)
	Pork price*turkey price	-0.063 (0.410)	-0.062 (0.400)	-0.063 (0.400)
	Chicken price*chicken price	-0.007 (0.030)	-0.025 (0.120)	-0.028 (0.130)
	Chicken price*turkey price	-0.009 (0.060)	-0.010 (0.060)	-0.011 (0.070)
	Turkey price*turkey price	0.143 (0.530)	0.133 (0.500)	0.129 (0.480)
Beef equation	Constant	-0.786 (5.480) ***	-0.794 (6.030) ***	-0.802 (5.940) ***
	Quarter 1	-0.709 (12.580) ***	-0.713 (12.390) ***	-0.714 (12.250) ***
	Quarter 2	-0.733 (13.020) ***	-0.733 (12.790) ***	-0.732 (12.710) ***
	Quarter 3	-0.719	-0.720	-0.721

		(12.810) ***	(12.650) ***	(12.530) ***
	Time	-0.045 (6.290) ***	-0.048 (5.450) ***	-0.045 (5.490) ***
	Lagged beef disappearance	-0.040 (2.980) ***	-0.036 (2.370) ***	-0.038 (2.570) ***
	Risk perception	0.807 (2.850) ***	0.907 (2.990) ***	0.952 (3.100) ***
Pork equation	Constant	-0.478 (3.790) ***	-0.468 (3.880) ***	-0.465 (3.640) ***
	Quarter 1	-0.710 (12.510) ***	-0.707 (12.310) ***	-0.708 (12.500) ***
	Quarter 2	-0.681 (11.780) ***	-0.681 (11.830) ***	-0.680 (120.000) ***
	Quarter 3	-0.693 (11.250) ***	-0.695 (12.190) ***	-0.692 (12.170) ***
	Time	-0.039 (6.200) ***	-0.041 (5.620) ***	-0.041 (5.810) ***
	Lagged pork disappearance	-0.017 (1.240)	-0.016 (1.160)	-0.015 (1.010)
	Risk perception	-0.010 (0.020)	-0.127 (0.260)	-0.248 (0.410)
Chicken equation	Constant	0.093 (0.820)	0.088 (0.740)	0.108 (0.960)
	Quarter 1	-0.661 (11.650) ***	-0.665 (11.750) ***	-0.664 (11.690) ***
	Quarter 2	-0.667 (11.900) ***	-0.667 (11.100) ***	-0.669 (11.650) ***
	Quarter 3	-0.672 (12.650) ***	-0.669 (12.100) ***	-0.669 (11.830) ***
	Time	-0.020 (5.530) ***	-0.021 (4.950) ***	-0.022 (5.280) ***
	Lagged chicken disappearance	-0.005 (0.340)	-0.005 (0.280)	-0.003 (0.210)
	Risk perception	-0.382 (1.360)	-0.487 (1.430)	-0.426 (1.140)
Turkey equation	Constant	0.172 (0.920)	0.174 (0.950)	0.160 (0.890)
	Quarter 1	-0.682 (11.190) ***	-0.679 (11.590) ***	-0.679 (11.210) ***
	Quarter 2	-0.686 (12.100)	-0.681 (11.630)	-0.679 (11.620)

		***	***	***
	Quarter 3	-0.683 (11.720) ***	-0.687 (11.910) ***	-0.685 (11.660) ***
	Time	-0.004 (0.730)	-0.004 (0.830)	-0.004 (0.820)
	Lagged turkey disappearance	-0.009 (0.600)	-0.009 (0.600)	-0.009 (0.560)
	Risk perception	0.209 (0.300)	0.215 (0.260)	0.435 (0.350)
Total Meat expenditure equation	Constant	0.210 (1.460)	-0.070 (0.300)	0.160 (0.550)
	Quarter 1	-0.038 (1.240)	-0.041 (1.340)	-0.039 (1.310)
	Quarter 2	0.002 (0.050)	0.001 (0.010)	-0.005 (0.170)
	Quarter 3	0.004 (0.140)	0.001 (0.010)	0.004 (0.140)
	Stone price index	0.287 (7.630) ***	0.223 (3.690) ***	0.328 (6.450) ***
	Per capita disposable income	0.282 (2.930) ***	0.540 (5.370) ***	0.420 (2.140) **
	Lagged meat expenditure	0.343 (3.750) ***	0.390 (3.890) ***	0.227 (3.820) ***
	time	-0.114 (2.810) ***	-0.031 (0.590)	-0.130 (1.950) *
	Risk perception	0.005 (0.100)	0.025 (0.590)	0.130 (1.780) *

a: Model 1 is estimated by assuming that the risk perceptions over BSE started rising when the first BSE-infected cow found in Canada in the first quarter of 1992. Model 2 is estimated by assuming that the risk perceptions over BSE started rising after the announcement of possible relationship between mad cow disease and human vCJD in the first quarter of 1996. Model 3 is estimated by assuming that the risk perceptions over BSE started rising after the first domestic BSE-infected cow found in Alberta in the second quarter of 2003.
b: The t statistics are reported in parentheses. ”*”,”**”,”***”, represents 95%, 97.5% and 99% significant levels.

Table C.3 Friedman and Kendall Tests in Different Groups and Different Time Periods Based on Quarterly Home-Scan Panel Data

Mean Rank												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Number of sample	16515				4076				1437			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Before section in R	1.820	1.850	1.930	2.080	1.600	1.650	1.800	2.130	1.580	1.640	1.800	2.140
Spaning section in R	2.020	2.040	2.080	2.080	2.090	2.160	2.270	2.240	2.110	2.190	2.300	2.240
After section in R	2.170	2.110	1.990	1.840	2.310	2.190	1.930	1.630	2.30	2.170	1.910	1.620
Friedman Test												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Chi-Square	3812	2223	783	2311	2067	1426	911	1576	738	532	371	594
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Kendall's W Test												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Kendall's Coefficient of Concordance	0.120	0.070	0.020	0.070	0.250	0.180	0.110	0.190	0.260	0.190	0.130	0.210
Chi-Square	3812	2223	783	2311	2067	1426	911	1576	738	532	371	594
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Mean Rank												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Number of sample	1552				849				238			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Before section in R	1.590	1.650	1.810	2.140	1.610	1.650	1.790	2.10	1.660	1.690	1.810	2.060
Spaning section in R	2.080	2.150	2.250	2.230	2.080	2.150	2.280	2.250	2.050	2.10	2.220	2.230
After section in R	2.330	2.20	1.940	1.630	2.310	2.190	1.930	1.650	2.30	2.210	1.970	1.710
Friedman Test												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Chi-Square	815	527	299	591	412	296	205	324	106	78	42	72
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Kendall's W Test												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Break point (Year, quarter)	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3	2003.3	2004.1	2005.1	2006.3
Kendall's Coefficient of Concordance	0.260	0.170	0.10	0.190	0.240	0.170	0.120	0.190	0.220	0.160	0.090	0.150
Chi-Square	815	527	299	591	412	296	205	324	106	78	42	72
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table C.4 Friedman and Kendall Tests in Different Groups and Different Time Periods Based on Annual Home-Scan Panel Data

Mean Rank												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Number of sample	16515				4076				1437			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Before section in R	1.990	2.000	2.000	2.010	1.980	1.990	2.000	2.020	1.980	1.990	2.000	2.020
Spaning section in R	2.010	2.010	2.010	2.000	2.010	2.020	2.020	2.000	2.010	2.020	2.020	2.000
After section in R	2.000	2.000	1.990	1.990	2.010	1.990	1.980	1.980	2.000	1.990	1.980	1.980
Friedman Test												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Chi-Square	163	73	99	198	61	57	83	123	23	30	31	41
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Kendall's W Test												
Data	All quarterly data				Quarterly survey data				Quarterly survey data for group 1			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Kendall's Coefficient of Concordance	0.003	0.002	0.003	0.006	0.007	0.007	0.010	0.015	0.008	0.011	0.011	0.014
Chi-Square	102	73	99	198	61	57	83	123	23	30	31	41
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Mean Rank												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Before section in R	1.980	1.990	2.000	2.020	1.980	2.000	2.000	2.020	1.980	1.980	1.990	2.000
Spaning section in R	2.010	2.020	2.020	2.000	2.010	2.010	2.010	2.000	2.010	2.020	2.020	2.020
After section in R	2.010	1.990	1.980	1.970	2.000	1.990	1.980	1.980	2.010	2.000	1.990	1.980
Friedman Test												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Chi-Square	22	19	32	52	14	6	17	29	5	6	5	6
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.054	0.001	0.001	0.097	0.050	0.097	0.05
Kendall's W Test												
Data	Quarterly survey data for group 2				Quarterly survey data for group 3				Quarterly survey data for group 4			
Break point (Year, quarter)	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006
Kendall's Coefficient of Concordance	0.007	0.006	0.010	0.017	0.008	0.003	0.010	0.017	0.010	0.013	0.010	0.013
Chi-Square	22	19	32	52	14	6	17	29	5	6	5	6
D.F.	2	2	2	2	2	2	2	2	2	2	2	2
Sig.	0.001	0.001	0.001	0.001	0.001	0.054	0.001	0.001	0.097	0.050	0.097	0.050

Table C.5 Estimation of Demand System Based on Yearly Panel Data and Predictive Difference Approach-Group 1 ("Confident Group")

Equation	Variable	2002-2003[a]	2004-2005	2006-2007	2004-2007	2002-2007
Total Meat expenditure equation	Constant[b]	7.170 (4.210) ***	2.930 (3.300) ***	3.390 (2.850) ***	3.470 (5.900) ***	4.500 (8.170) ***
	Region1	0.270 (1.250)	0.360 (1.850)	0.510 (2.860) ***	0.430 (3.650) ***	0.480 (4.900) ***
	Region2	0.130 (0.660)	0.190 (1.790)	0.430 (3.430) ***	0.320 (4.060) ***	0.300 (3.930) ***
	Region3	0.240 (1.460)	0.080 (0.780)	0.180 (1.660)	0.130 (1.980) *	0.190 (3.070) ***
	Region4	0.080 (0.430)	0.050 (0.440)	0.010 (-0.020)	0.020 (0.190)	0.080 (1.090)
	Region5	0.380 (2.200) **	0.010 (-0.040)	0.140 (1.170)	0.060 (0.900)	0.160 (2.400) ***
	household size1	-1.030 (-2.020) *	-0.330 (-1.130)	-0.260 (-0.840)	-0.300 (-1.510)	-0.630 (-3.940) ***
	household size2	-0.220 (-0.450)	0.010 (0.020)	0.060 (0.190)	0.030 (0.150)	-0.070 (-0.440)
	household size3	-0.440 (-0.900)	-0.040 (-0.150)	-0.080 (-0.300)	-0.060 (-0.350)	-0.210 (-1.420)
	household size4	-0.140 (-0.30)	0.140 (0.440)	0.040 (0.130)	0.080 (0.410)	0.020 (0.160)
	age and presence of children 1	0.300 (1.300)	0.110 (0.610)	0.210 (0.980)	0.160 (1.210)	0.230 (2.170) *
	age and presence of children 2	0.370 (0.630)	-0.040 (-0.140)	0.110 (0.300)	0.040 (0.170)	0.160 (0.920)
	age and presence of children 3	0.590 (1.260)	0.060 (0.260)	0.390 (0.940)	0.230 (1.120)	0.370 (2.190) **
	age and presence of children 6	0.600 (1.020)	0.050 (0.150)	0.200 (0.530)	0.110 (0.480)	0.300 (1.630)
	age of household head 1	-0.360 (-2.020) *	-0.070 (-0.550)	-0.220 (-1.700)	-0.150 (-1.840)	-0.230 (-3.110) ***
	age of household head 3	-0.080 (-0.560)	0.010 (-0.010)	0.010 (0.050)	0.010 (-0.050)	-0.010 (-0.220)
	age of household head 4	0.100 (0.640)	0.010 (0.070)	0.010 (0.050)	0.010 (0.070)	0.040 (0.640)
	Education level of household head 1	-0.140 (-0.760)	0.110 (0.850)	0.240 (1.740)	0.180 (2.090) *	0.130 (1.650)

	Education level of household head 2	0.090 (0.510)	0.160 (1.540)	0.220 (1.690)	0.190 (2.430) ***	0.200 (3.020) ***
	Education level of household head 3	0.160 (0.760)	0.090 (0.770)	0.350 (2.380) ***	0.220 (2.620) ***	0.240 (3.120) ***
	Education level of household head 4	0.080 (0.510)	0.220 (2.120) *	0.180 (1.560)	0.200 (2.710) ***	0.220 (3.410) ***
	Education level of household head 5	-0.010 (-0.070)	0.160 (1.300)	0.230 (1.870)	0.190 (2.440) ***	0.170 (2.170) *
	Annual income 1	-0.540 (-2.270) **	-0.130 (-0.930)	-0.800 (-5.840) ***	-0.470 (-5.210) ***	-0.590 (-7.060) ***
	Annual income 2	-0.310 (-1.700)	-0.180 (-1.610)	-0.290 (-2.090) *	-0.240 (-2.850) ***	-0.310 (-4.140) ***
	Annual income 3	-0.340 (-1.890) *	-0.050 (-0.450)	-0.180 (-1.500)	-0.120 (-1.510)	-0.220 (-2.970) ***
	Annual income 4	-0.130 (-0.720)	-0.060 (-0.530)	-0.120 (-0.850)	-0.090 (-1.120)	-0.130 (-1.800)
	Annual income 5	0.150 (0.850)	0.010 (0.130)	-0.120 (-1.020)	-0.050 (-0.690)	0.010 (0.110)
	Origin as rural	-0.460 (-3.930) ***	-0.180 (-2.440) ***	-0.090 (-1.010)	-0.130 (-2.580) ***	-0.280 (-5.880) ***
	Stone price index	-1.220 (-1.520)	-0.610 (-1.500)	-0.690 (-1.230)	-0.790 (-2.950) ***	-0.670 (-2.610) ***
	Lagged meat expenditure	0.200 (16.050) ***	0.650 (54.370) ***	0.590 (47.510) ***	0.620 (76.220) ***	0.420 (700.000) ***
Demographics in beef equation	Constant	0.380 (1.120)	-0.050 (-0.230)	-0.020 (-0.100)	0.250 (3.450) ***	0.160 (2.900) ***
	Region1	0.250 (0.740)	0.340 (1.590)	-0.160 (-1.070)	-0.010 (-0.230)	0.050 (1.010)
	Region2	-0.110 (-0.680)	-0.020 (-0.180)	-0.010 (-0.230)	0.030 (0.980)	0.020 (0.880)
	Region3	-0.450 (-4.080) ***	-0.010 (-0.190)	0.280 (4.690) ***	-0.010 (-0.180)	-0.010 (-0.210)
	Region4	1.220 (0.810)	0.230 (1.040)	0.480 (1.400)	-0.060 (-0.770)	-0.070 (-1.180)
	Region5	-0.140 (-0.170)	0.170 (0.730)	-0.260 (-1.450)	0.020 (0.310)	0.050 (0.800)
	household size1	-0.470 (-1.760)	-0.200 (-1.600)	0.130 (1.580)	-0.020 (-0.360)	-0.050 (-1.340)
	household size2	5.640 (3.490) ***	-2.470 (-30.000) ***	-0.940 (-0.990)	0.300 (1.290)	0.720 (4.140) ***
	household size3	-4.460 (-2.230)	1.560 (1.780)	0.470 (0.950)	-0.220 (-1.020)	-0.700 (-4.280)

		**				***
	household size4	-12.480 (-3.800) ***	1.250 (1.130)	2.530 (1.260)	-0.560 (-2.030) *	-0.900 (-4.140) ***
	age and presence of children 1	-0.340 (-0.890)	-0.070 (-0.490)	-0.120 (-1.590)	-0.120 (-2.500) ***	-0.150 (-3.870) ***
	age and presence of children 2	-0.100 (-1.300)	-0.010 (-0.170)	-0.040 (-1.200)	0.010 (0.120)	-0.010 (-0.970)
	age and presence of children 3	0.050 (0.760)	0.050 (1.800)	0.010 (0.430)	0.040 (3.070) ***	0.030 (3.250) ***
	age and presence of children 6	-0.020 (-0.590)	0.010 (-0.020)	0.020 (1.430)	0.010 (-0.110)	-0.010 (-1.700)
	age of household head 1	0.010 (0.330)	0.020 (0.820)	0.010 (-0.290)	0.010 (0.860)	0.010 (0.050)
	age of household head 3	0.050 (1.040)	0.010 (0.290)	-0.060 (-2.850) ***	-0.020 (-2.630) ***	-0.020 (-2.430) ***
	age of household head 4	0.070 (1.840)	0.010 (0.180)	0.060 (1.550)	0.030 (1.480)	0.050 (2.770) ***
	Education level of household head 1	0.030 (0.800)	-0.030 (-0.800)	0.010 (0.350)	-0.010 (-0.320)	0.010 (0.510)
	Education level of household head 2	0.020 (0.640)	-0.110 (-2.610) ***	0.010 (0.130)	-0.050 (-2.030) *	-0.020 (-1.140)
	Education level of household head 3	0.010 (0.340)	-0.060 (-1.250)	-0.020 (-0.660)	-0.040 (-1.520)	-0.020 (-0.980)
	Education level of household head 4	0.050 (2.300) **	0.020 (1.020)	0.040 (1.670)	0.030 (2.600) ***	0.040 (3.950) ***
	Education level of household head 5	0.040 (0.960)	-0.040 (-1.700)	-0.010 (-0.160)	-0.020 (-1.120)	0.010 (0.870)
	Annual income 1	0.040 (1.360)	0.070 (1.670)	0.040 (0.880)	0.050 (2.080) *	0.050 (3.150) ***
	Annual income 2	0.050 (0.980)	-0.030 (-0.660)	0.040 (1.240)	0.010 (0.700)	0.020 (1.210)
	Annual income 3	0.020 (1.500)	0.010 (-0.080)	0.020 (1.460)	0.010 (1.070)	0.010 (2.090) *
	Annual income 4	0.030 (1.950) *	0.010 (0.250)	0.020 (1.630)	0.010 (1.540)	0.020 (2.790) ***
	Annual income 5	0.020 (1.190)	0.010 (0.920)	0.010 (0.590)	0.010 (1.410)	0.010 (2.050) *
	Origin as rural	-0.030	0.040	0.010	0.030	0.010

		(-1.530)	(2.410) ***	(0.810)	(2.730) ***	(1.820)
Demographics in pork equation	Constant	-0.010 (-0.690)	0.010 (0.060)	-0.010 (-1.170)	-0.010 (-0.780)	-0.010 (-1.100)
	Region1	-0.050 (-3.140) ***	-0.030 (-1.830)	-0.020 (-1.630)	-0.020 (-2.810) ***	-0.030 (-4.220) ***
	Region2	0.010 (-0.270)	0.010 (1.060)	0.010 (-0.340)	0.010 (0.500)	0.010 (0.380)
	Region3	0.010 (0.040)	0.020 (1.010)	-0.020 (-1.480)	0.010 (-0.220)	0.010 (0.010)
	Region4	0.060 (2.210) **	0.010 (0.440)	0.010 (-0.180)	0.010 (0.290)	0.020 (2.030) *
	Region5	0.050 (3.290) ***	0.020 (0.980)	0.030 (2.130) *	0.020 (2.330) **	0.030 (4.380) ***
	household size1	0.060 (3.710) ***	0.020 (1.070)	0.010 (-0.080)	0.010 (0.780)	0.020 (3.050) ***
	household size2	0.010 (0.760)	-0.030 (-2.190) **	0.010 (0.900)	-0.010 (-1.150)	0.010 (-0.590)
	household size3	0.050 (3.460) ***	0.010 (0.070)	-0.010 (-1.300)	-0.010 (-0.900)	0.010 (2.110) *
	household size4	0.010 (1.240)	0.010 (0.150)	0.010 (0.260)	0.010 (0.430)	0.010 (0.810)
	age and presence of children 1	-2.630 (-2.170) *	0.100 (0.270)	0.030 (0.180)	-0.290 (-2.540) ***	-0.570 (-6.780) ***
	age and presence of children 2	-0.060 (-0.510)	0.280 (2.010) *	0.150 (1.790)	0.050 (1.730)	0.030 (1.230)
	age and presence of children 3	-0.020 (-0.150)	0.140 (1.740)	0.080 (1.410)	0.010 (0.330)	-0.010 (-0.610)
	age and presence of children 6	0.170 (1.280)	0.070 (1.220)	0.030 (1.010)	0.060 (3.30) ***	0.070 (5.370) ***
	age of household head 1	0.110 (1.090)	-0.020 (-0.420)	0.040 (1.020)	-0.030 (-1.750)	-0.010 (-1.150)
	age of household head 3	0.200 (1.960) *	0.010 (0.300)	0.150 (2.650) ***	0.040 (2.510) ***	0.030 (2.350) ***
	age of household head 4	-0.020 (-0.270)	0.100 (1.720)	-0.250 (-3.170) ***	-0.080 (-2.040) *	-0.060 (-1.890) *
	Education level of household head 1	-0.010 (-0.170)	0.080 (1.490)	-0.220 (-2.840) ***	-0.070 (-1.860)	-0.050 (-1.570)
	Education level of household head 2	0.020 (0.300)	0.160 (2.490) ***	-0.170 (-2.20) **	-0.010 (-0.150)	0.010 (0.160)

	Education level of household head 3	-0.020 (-0.340)	0.040 (0.680)	-0.220 (-2.920) ***	-0.090 (-2.360) ***	-0.060 (-2.120) *
	Education level of household head 4	-0.100 (-2.330) **	-0.160 (-4.610) ***	-0.150 (-4.340) ***	-0.150 (-6.820) ***	-0.130 (-7.160) ***
	Education level of household head 5	-0.130 (-1.520)	0.050 (0.510)	0.010 (-0.040)	0.020 (0.300)	-0.030 (-0.630)
	Annual income 1	-0.030 (-0.410)	-0.190 (-2.740) ***	-0.190 (-2.650) ***	-0.190 (-4.520) ***	-0.120 (-3.410) ***
	Annual income 2	-0.130 (-1.600)	-0.020 (-0.200)	-0.280 (-3.820) ***	-0.160 (-3.460) ***	-0.140 (-4.170) ***
	Annual income 3	-0.040 (-1.380)	0.010 (0.080)	-0.080 (-3.670) ***	-0.040 (-2.760) ***	-0.040 (-3.580) ***
	Annual income 4	-0.060 (-2.020) *	0.010 (0.010)	-0.010 (-0.580)	-0.010 (-0.550)	-0.020 (-1.960) *
	Annual income 5	-0.070 (-2.900) ***	0.010 (0.010)	0.010 (-0.070)	0.010 (-0.130)	-0.020 (-1.840)
	Origin as rural	-0.030 (-0.900)	0.060 (2.140) *	-0.010 (-0.480)	0.020 (1.350)	0.010 (0.670)
Demographics in chicken equation	Constant	0.010 (-0.090)	0.040 (1.700)	-0.020 (-1.080)	0.010 (0.480)	0.010 (0.260)
	Region1	-0.030 (-0.820)	0.050 (1.810)	-0.030 (-1.050)	0.010 (0.700)	0.010 (0.330)
	Region2	0.060 (2.340) ***	-0.030 (-1.380)	-0.050 (-2.220) **	-0.040 (-2.600) ***	0.010 (-0.260)
	Region3	0.010 (0.260)	0.010 (0.430)	-0.030 (-1.180)	-0.010 (-0.450)	0.010 (-0.050)
	Region4	-0.010 (-0.370)	-0.050 (-1.730)	0.070 (2.660) ***	0.010 (0.800)	0.010 (0.620)
	Region5	0.040 (1.230)	-0.020 (-0.710)	-0.030 (-1.240)	-0.020 (-1.350)	-0.010 (-0.580)
	household size1	0.030 (0.930)	-0.030 (-1.290)	0.020 (0.970)	0.010 (-0.180)	0.010 (0.340)
	household size2	-0.030 (-0.860)	-0.050 (-1.950) *	0.040 (1.680)	0.010 (-0.260)	-0.010 (-0.630)
	household size3	-0.040 (-1.570)	-0.090 (-40.000) ***	-0.010 (-0.420)	-0.050 (-3.250) ***	-0.050 (-3.820) ***
	household size4	-0.010 (-0.380)	0.030 (1.950) *	-0.040 (-2.620) ***	-0.010 (-0.530)	-0.010 (-0.990)
	age and presence of children 1	-0.640 (-0.640)	0.320 (1.110)	-0.100 (-0.650)	-0.030 (-0.370)	-0.050 (-0.960)

	age and presence of children 2	-0.250 (-2.130) *	-0.060 (-0.510)	0.010 (0.130)	-0.150 (-7.210) ***	-0.140 (-8.150) ***
	age and presence of children 3	0.010 (0.030)	-0.020 (-0.310)	0.050 (0.640)	-0.070 (-4.320) ***	-0.060 (-4.710) ***
	age and presence of children 6	-0.100 (-0.800)	-0.040 (-0.690)	-0.150 (-4.180) ***	-0.090 (-6.460) ***	-0.090 (-7.770) ***
	age of household head 1	0.040 (0.450)	0.040 (0.760)	0.020 (0.420)	-0.030 (-2.270) **	-0.030 (-3.010) ***
	age of household head 3	0.130 (1.170)	0.050 (1.140)	0.090 (1.140)	-0.020 (-1.160)	-0.030 (-2.590) ***
	age of household head 4	0.040 (0.790)	-0.050 (-0.780)	0.140 (1.970) *	0.040 (1.070)	0.040 (1.630)
	Education level of household head 1	0.070 (1.550)	-0.050 (-0.850)	0.120 (1.730)	0.030 (0.850)	0.040 (1.680)
	Education level of household head 2	0.030 (0.610)	-0.010 (-0.10)	0.100 (1.420)	0.040 (1.090)	0.040 (1.540)
	Education level of household head 3	0.040 (0.800)	-0.030 (-0.500)	0.080 (1.210)	0.030 (0.710)	0.030 (1.100)
	Education level of household head 4	0.060 (1.750)	0.030 (0.760)	0.050 (1.670)	0.040 (1.590)	0.040 (2.430) ***
	Education level of household head 5	-0.010 (-0.160)	0.010 (-0.010)	-0.010 (-0.120)	-0.010 (-0.120)	-0.010 (-0.400)
	Annual income 1	-0.030 (-0.490)	-0.010 (-0.10)	0.010 (0.160)	0.010 (-0.020)	-0.020 (-0.560)
	Annual income 2	0.110 (1.010)	-0.090 (-1.470)	0.080 (1.040)	0.010 (0.080)	0.040 (1.320)
	Annual income 3	0.040 (1.860)	0.030 (1.430)	0.050 (2.580) ***	0.040 (3.070) ***	0.040 (4.010) ***
	Annual income 4	0.090 (3.880) ***	0.030 (1.780)	0.020 (1.250)	0.030 (2.560) ***	0.040 (4.730) ***
	Annual income 5	0.060 (3.150) ***	0.030 (2.100) *	0.010 (0.600)	0.020 (2.120) *	0.030 (3.860) ***
	Origin as rural	-0.020 (-1.010)	-0.060 (-2.710) ***	-0.070 (-4.340) ***	-0.070 (-5.600) ***	-0.060 (-5.440) ***
Demographics in turkey equation	Constant	0.010 (0.060)	-0.020 (-1.200)	-0.020 (-1.250)	-0.030 (-1.980) *	-0.020 (-1.850)
	Region1	0.040 (1.270)	0.010 (0.090)	-0.040 (-2.260) **	-0.020 (-1.650)	-0.010 (-0.610)

	Region2	-0.010 (-0.570)	0.020 (0.700)	-0.030 (-1.520)	-0.010 (-0.570)	-0.010 (-0.880)
	Region3	-0.010 (-0.380)	-0.060 (-3.010) ***	0.010 (-0.220)	-0.030 (-2.320) **	-0.030 (-2.430) ***
	Region4	0.090 (2.600) ***	-0.020 (-0.780)	-0.040 (-1.780)	-0.030 (-2.040) *	0.010 (-0.340)
	Region5	-0.030 (-1.520)	-0.010 (-0.250)	-0.050 (-2.530) ***	-0.030 (-1.960) *	-0.030 (-2.550) ***
	household size1	-0.010 (-0.270)	0.020 (0.740)	-0.040 (-1.930) *	-0.010 (-0.920)	-0.010 (-0.970)
	household size2	0.040 (1.250)	0.020 (0.710)	-0.020 (-0.980)	0.010 (-0.020)	0.010 (0.640)
	household size3	0.010 (0.080)	0.030 (1.170)	0.010 (-0.050)	0.010 (0.930)	0.010 (0.880)
	household size4	-0.040 (-2.600) ***	-0.030 (-2.220) **	0.010 (0.880)	-0.010 (-1.150)	-0.020 (-2.560) ***
	age and presence of children 1	2.260 (1.860)	-1.260 (-3.330) ***	-0.290 (-1.330)	-0.340 (-2.520) ***	-0.090 (-0.940)
	age and presence of children 2	0.490 (3.700) ***	-0.380 (-2.740) ***	-0.280 (-1.720)	-0.010 (-0.390)	0.020 (0.690)
	age and presence of children 3	-0.060 (-0.250)	-0.300 (-3.840) ***	-0.240 (-2.320) **	-0.080 (-3.940) ***	-0.060 (-3.540) ***
	age and presence of children 6	-0.040 (-0.290)	-0.080 (-1.340)	0.030 (0.640)	-0.030 (-1.370)	-0.030 (-2.170) *
	age of household head 1	-0.210 (-1.290)	-0.100 (-2.160) *	-0.130 (-1.740)	-0.010 (-0.770)	-0.020 (-1.430)
	age of household head 3	-0.400 (-1.900) *	-0.100 (-2.070) *	-0.220 (-1.930) *	-0.030 (-1.500)	-0.020 (-0.990)
	age of household head 4	-0.070 (-0.840)	-0.100 (-1.020)	0.040 (0.380)	-0.030 (-0.470)	-0.040 (-1.100)
	Education level of household head 1	-0.040 (-0.490)	-0.040 (-0.410)	0.060 (0.620)	0.010 (0.140)	-0.010 (-0.310)
	Education level of household head 2	-0.040 (-0.560)	-0.030 (-0.320)	0.130 (1.290)	0.050 (0.780)	0.010 (0.310)
	Education level of household head 3	0.010 (-0.010)	0.010 (-0.010)	0.090 (0.930)	0.040 (0.750)	0.030 (0.770)
	Education level of household head 4	0.010 (-0.020)	0.070 (1.470)	0.060 (1.590)	0.070 (2.410) ***	0.050 (2.200) **
	Education level	0.030	-0.160	0.010	-0.070	-0.030

	of household head 5	(0.360)	(-1.870)	(0.170)	(-1.300)	(-0.640)
	Annual income 1	0.010 (0.220)	-0.020 (-0.190)	0.080 (10.000)	0.040 (0.730)	0.030 (0.860)
	Annual income 2	0.010 (0.130)	0.160 (1.180)	0.080 (0.760)	0.100 (1.560)	0.060 (1.650)
	Annual income 3	0.010 (0.480)	0.010 (0.070)	-0.020 (-1.030)	-0.010 (-0.700)	0.010 (-0.300)
	Annual income 4	-0.010 (-0.430)	-0.040 (-2.170) *	-0.060 (-2.790) ***	-0.050 (-3.900) ***	-0.040 (-3.520) ***
	Annual income 5	-0.030 (-1.160)	-0.030 (-1.580)	-0.040 (-2.090) *	-0.040 (-2.940) ***	-0.030 (-3.450) ***
	Origin as rural	0.040 (1.190)	-0.020 (-0.670)	0.060 (2.440) ***	0.030 (1.560)	0.030 (2.020) *
Beef, pork, chicken, turkey equations	Beef price*seafood price	0.010 (0.190)	-0.060 (-2.890) ***	0.020 (0.820)	-0.020 (-1.380)	-0.010 (-0.930)
	Chicken price*seafood price	0.040 (1.150)	0.010 (0.010)	0.050 (1.970) *	0.030 (1.520)	0.030 (1.790)
	Turkey price*seafood price	-0.030 (-1.120)	-0.020 (-1.100)	0.020 (1.110)	0.010 (-0.050)	-0.010 (-1.260)
	Seafood price*seafood price	0.040 (1.170)	0.010 (0.140)	-0.020 (-0.780)	-0.010 (-0.420)	0.010 (0.250)
	Beef price*turkey price	-0.040 (-1.040)	0.060 (2.060) *	0.040 (1.530)	0.050 (2.800) ***	0.020 (1.440)
	Chicken price*turkey price	-0.020 (-0.690)	0.010 (-0.010)	0.060 (2.640) ***	0.030 (1.980) *	0.010 (0.920)
	Turkey price*turkey price	-0.050 (-1.440)	0.070 (2.910) ***	0.060 (2.710) ***	0.070 (4.370) ***	0.030 (2.520) ***
	Beef price*chicken price	-0.030 (-0.970)	0.030 (1.170)	-0.010 (-0.420)	0.010 (0.690)	0.010 (-0.170)
	Chicken price*chicken price	-0.020 (-0.840)	0.060 (2.300) **	0.070 (3.390) ***	0.070 (4.300) ***	0.040 (3.010) ***
	Beef price*beef price	0.040 (1.950) *	0.010 (0.250)	0.030 (1.760)	0.020 (1.800)	0.030 (3.280) ***
	Lagged beef disappearance	-0.080 (-16.290) ***	-0.110 (-24.390) ***	-0.100 (-26.190) ***	-0.100 (-36.620) ***	-0.090 (-40.770) ***
	Lagged pork disappearance	-0.090 (-16.190) ***	-0.120 (-24.540) ***	-0.100 (-26.710) ***	-0.100 (-37.260) ***	-0.100 (-41.650) ***
	Lagged chicken disappearance	-0.050 (-15.550)	-0.060 (-21.40)	-0.060 (-22.690)	-0.060 (-31.80)	-0.050 (-36.290)

		***	***	***	***	***
	Lagged turkey disappearance	-0.030 (-16.070) ***	-0.030 (-21.260) ***	-0.030 (-24.350) ***	-0.030 (-33.110) ***	-0.030 (-38.370) ***
	Lagged seafood disappearance	-0.190 (-14.910) ***	-0.220 (-21.870) ***	-0.150 (-20.590) ***	-0.170 (-31.260) ***	-0.170 (-36.310) ***

a: Due to the fact that the models based on period 2002-2003,2004-2005 and 2006-2007 have high multicollinearity among variables (condition number on period 2002-2003: 241; condition number on period 2004-2005: 208; condition number on period 2006-2007: 352), the parameter significance may not be reliable. Therefore, we use the models based on 2002-2007 and 2004-2007 to evaluate the significance of parameters.
b: "*,**,***" represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses.

Table C.6 Estimation of Demand System Based on Yearly Panel Data and Predictive Difference Approach-Group 2 ("Neutral Group")

Equation	Variable	2002-2003[a]	2004-2005	2006-2007	2004-2007	2002-2007
Total Meat expenditure equation	Constant[b]	4.370 (2.50) ***	1.860 (20.000) *	3.250 (3.600) ***	3.240 (6.210) ***	3.570 (7.130) ***
	Region1	0.360 (1.780)	0.430 (3.470) ***	0.510 (4.220) ***	0.460 (5.920) ***	0.500 (6.770) ***
	Region2	0.130 (0.730)	0.110 (1.010)	0.460 (4.630) ***	0.290 (4.450) ***	0.270 (4.480) ***
	Region3	0.080 (0.530)	0.130 (1.250)	0.150 (1.640)	0.130 (2.050) *	0.150 (2.760) ***
	Region4	0.290 (1.510)	0.260 (1.60)	0.240 (1.770)	0.220 (2.30) **	0.310 (3.70) ***
	Region5	0.420 (1.610)	0.220 (1.690)	0.220 (1.80)	0.210 (2.570) ***	0.300 (3.940) ***
	household size1	-1.070 (-2.220) **	-0.480 (-1.490)	-0.40 (-1.760)	-0.450 (-2.960) ***	-0.690 (-4.950) ***
	household size2	-0.500 (-1.060)	-0.170 (-0.550)	-0.130 (-0.60)	-0.150 (-1.030)	-0.260 (-1.960) *
	household size3	-0.240 (-0.560)	-0.110 (-0.360)	0.010 (0.030)	-0.050 (-0.380)	-0.100 (-0.810)
	household size4	-0.080 (-0.180)	-0.030 (-0.110)	0.150 (0.670)	0.040 (0.330)	0.030 (0.260)
	age and presence of children 1	-0.150 (-0.560)	0.050 (0.370)	0.040 (0.250)	0.050 (0.470)	-0.010 (-0.150)
	age and presence of children 2	-0.280 (-0.50)	-0.050 (-0.180)	-0.260 (-0.950)	-0.150 (-0.920)	-0.210 (-1.340)
	age and presence of children 3	0.010 (0.020)	0.070 (0.210)	0.130 (0.320)	0.100 (0.470)	0.090 (0.500)
	age and presence of children 6	-0.030 (-0.060)	0.160 (0.400)	-0.010 (-0.030)	0.080 (0.270)	0.060 (0.270)

	age of household head 1	-0.020 (-0.080)	-0.220 (-2.040) *	-0.080 (-0.720)	-0.160 (-2.30) **	-0.140 (-2.040) *
	age of household head 3	-0.120 (-0.870)	-0.100 (-1.140)	-0.070 (-0.780)	-0.090 (-1.540)	-0.100 (-1.730)
	age of household head 4	-0.010 (-0.080)	-0.10 (-1.110)	0.010 (0.110)	-0.050 (-0.910)	-0.030 (-0.530)
	Education level of household head 1	0.240 (1.470)	-0.170 (-1.340)	0.150 (1.260)	0.010 (0.040)	0.070 (0.950)
	Education level of household head 2	0.410 (2.240) **	0.090 (0.760)	0.150 (1.390)	0.120 (1.570)	0.230 (3.260) ***
	Education level of household head 3	0.480 (2.410) ***	-0.100 (-0.820)	0.140 (1.370)	0.030 (0.390)	0.160 (2.350) ***
	Education level of household head 4	0.260 (1.710)	0.030 (0.280)	0.110 (1.120)	0.080 (1.100)	0.150 (2.470) ***
	Education level of household head 5	0.280 (1.600)	-0.030 (-0.230)	0.100 (0.850)	0.030 (0.410)	0.130 (1.710)
	Annual income 1	-0.550 (-2.880) ***	-0.310 (-2.320) **	-0.350 (-2.510) ***	-0.330 (-3.770) ***	-0.440 (-5.530) ***
	Annual income 2	-0.260 (-1.270)	-0.110 (-0.840)	-0.110 (-0.880)	-0.120 (-1.430)	-0.160 (-2.060) *
	Annual income 3	-0.350 (-1.930) *	-0.120 (-0.970)	-0.140 (-1.100)	-0.130 (-1.700)	-0.210 (-2.870) ***
	Annual income 4	-0.220 (-1.320)	-0.090 (-0.830)	-0.070 (-0.530)	-0.080 (-1.060)	-0.120 (-1.740)
	Annual income 5	-0.040 (-0.260)	-0.100 (-0.900)	-0.100 (-0.970)	-0.110 (-1.540)	-0.100 (-1.540)
	Origin as rural	-0.270 (-2.420) ***	-0.070 (-0.900)	-0.090 (-1.300)	-0.080 (-1.690)	-0.140 (-3.300) ***
	Stone price index	0.210 (0.250)	0.240 (0.560)	-0.280 (-0.620)	-0.330 (-1.310)	-0.030 (-0.130)
	Lagged meat expenditure	0.190 (18.150) ***	0.590 (500.000) ***	0.490 (55.190) ***	0.530 (77.410) ***	0.380 (72.760) ***
Demographics in beef equation	Constant	0.290 (0.790)	0.330 (1.600)	0.200 (1.070)	0.090 (1.240)	0.050 (0.990)
	Region1	0.040 (0.120)	0.310 (1.590)	0.250 (1.710)	0.130 (2.100) *	0.110 (2.330) **
	Region2	0.090 (0.580)	-0.010 (-0.160)	0.050 (0.810)	0.010 (0.410)	0.010 (-0.10)
	Region3	-0.720 (-8.940) ***	-0.690 (-11.410) ***	-0.680 (-12.150) ***	-0.230 (-7.710) ***	-0.170 (-7.380) ***
	Region4	-0.030 (-0.070)	0.170 (0.720)	1.390 (5.030) ***	0.070 (0.990)	0.080 (1.330)

	Region5	-0.240 (-0.430)	-0.250 (-1.270)	-0.650 (-4.560) ***	-0.010 (-0.140)	-0.040 (-0.890)
	household size1	0.260 (0.800)	-0.150 (-1.520)	0.190 (3.090) ***	-0.070 (-1.880)	-0.060 (-1.910) *
	household size2	2.010 (1.230)	-1.070 (-1.630)	-3.180 (-4.460) ***	0.010 (0.020)	0.070 (0.400)
	household size3	-0.070 (-0.060)	0.610 (0.870)	0.840 (2.180) *	-0.020 (-0.100)	-0.070 (-0.450)
	household size4	-6.250 (-1.930) *	1.780 (1.860)	7.840 (5.100) ***	-0.330 (-1.170)	-0.290 (-1.310)
	age and presence of children 1	-0.110 (-0.420)	-0.30 (-2.370) ***	-0.210 (-2.530) ***	-0.130 (-2.490) ***	-0.130 (-3.620) ***
	age and presence of children 2	0.010 (-0.080)	-0.060 (-1.420)	-0.090 (-3.300) ***	-0.010 (-0.650)	-0.020 (-1.750)
	age and presence of children 3	0.010 (0.010)	0.010 (0.010)	-0.030 (-1.90) *	0.030 (2.900) ***	0.020 (30.000) ***
	age and presence of children 6	-0.010 (-0.270)	-0.010 (-0.550)	0.030 (2.460) ***	-0.010 (-0.710)	-0.010 (-1.060)
	age of household head 1	-0.030 (-0.850)	-0.020 (-1.090)	-0.050 (-3.450) ***	-0.010 (-1.080)	-0.010 (-1.790)
	age of household head 3	0.010 (0.230)	-0.010 (-0.470)	-0.070 (-3.680) ***	0.010 (-0.170)	0.010 (0.760)
	age of household head 4	-0.040 (-1.090)	0.010 (-0.050)	0.010 (0.060)	0.010 (0.010)	-0.010 (-0.580)
	Education level of household head 1	-0.030 (-0.850)	0.010 (0.040)	-0.010 (-0.230)	0.010 (-0.140)	-0.010 (-0.60)
	Education level of household head 2	0.010 (-0.130)	-0.020 (-0.420)	0.010 (-0.090)	-0.010 (-0.390)	-0.010 (-0.580)
	Education level of household head 3	-0.020 (-0.680)	-0.060 (-1.250)	0.010 (-0.050)	-0.030 (-1.030)	-0.030 (-1.570)
	Education level of household head 4	-0.030 (-1.490)	0.040 (1.650)	0.010 (0.640)	0.020 (1.960) *	0.010 (0.970)
	Education level of household head 5	0.020 (0.60)	0.070 (1.320)	0.030 (0.480)	0.050 (1.250)	0.040 (1.510)
	Annual income 1	0.010 (-0.060)	-0.010 (-0.320)	0.020 (0.820)	0.010 (0.280)	0.010 (0.380)
	Annual income 2	-0.040 (-1.230)	0.070 (1.490)	0.020 (0.530)	0.050 (1.470)	0.020 (0.850)
	Annual income 3	0.020 (1.430)	0.010 (0.650)	0.020 (1.490)	0.010 (1.660)	0.020 (2.360) ***
	Annual income 4	0.010 (1.130)	0.020 (1.950)	0.010 (-0.010)	0.010 (1.470)	0.010 (1.850)

			*			
	Annual income 5	0.010 (0.240)	0.010 (0.420)	-0.010 (-0.950)	0.010 (-0.490)	0.010 (-0.250)
	Origin as rural	0.010 (0.630)	-0.030 (-2.110) *	-0.020 (-1.650)	-0.020 (-2.850) ***	-0.010 (-2.050) *
Demographics in pork equation	Constant	0.020 (1.420)	-0.030 (-2.090) *	0.010 (-0.280)	-0.010 (-1.740)	0.010 (-0.680)
	Region1	-0.020 (-1.40)	-0.020 (-1.840)	-0.010 (-0.800)	-0.010 (-2.040) *	-0.020 (-2.780) ***
	Region2	0.020 (1.270)	-0.010 (-0.980)	-0.010 (-0.790)	-0.010 (-1.280)	0.010 (-0.470)
	Region3	0.010 (0.820)	0.010 (0.210)	0.010 (-0.220)	0.010 (0.010)	0.010 (0.350)
	Region4	0.050 (3.120) ***	0.010 (0.910)	0.040 (2.730) ***	0.030 (2.700) ***	0.030 (4.210) ***
	Region5	0.050 (3.160) ***	0.020 (1.230)	0.020 (1.220)	0.020 (1.830)	0.020 (3.520) ***
	household size1	0.030 (2.030) *	0.020 (1.800)	0.020 (1.250)	0.020 (2.330) **	0.020 (3.250) ***
	household size2	0.030 (1.880)	-0.010 (-1.190)	0.010 (0.380)	0.010 (-0.480)	0.010 (0.790)
	household size3	0.030 (2.540) ***	0.010 (-0.220)	0.010 (-0.260)	0.010 (-0.320)	0.010 (1.290)
	household size4	0.010 (0.650)	0.020 (2.170) *	0.010 (0.930)	0.010 (2.390) ***	0.010 (2.440) ***
	age and presence of children 1	-0.210 (-0.320)	-0.580 (-1.790)	-0.660 (-3.570) ***	-0.390 (-3.560) ***	-0.430 (-5.570) ***
	age and presence of children 2	-0.100 (-0.920)	0.200 (1.650)	0.340 (5.190) ***	0.080 (2.960) ***	0.050 (2.180) **
	age and presence of children 3	-0.070 (-0.570)	0.140 (2.040) *	0.20 (4.810) ***	0.060 (3.050) ***	0.020 (1.460)
	age and presence of children 6	-0.110 (-1.450)	0.030 (0.530)	-0.040 (-1.550)	0.010 (0.260)	-0.010 (-1.020)
	age of household head 1	-0.050 (-0.710)	-0.010 (-0.190)	0.110 (3.210) ***	-0.030 (-1.590)	-0.030 (-2.390) ***
	age of household head 3	0.040 (0.490)	0.060 (1.320)	0.170 (3.680) ***	0.010 (0.630)	0.010 (0.390)
	age of household head 4	0.010 (0.090)	0.070 (1.020)	-0.090 (-1.130)	-0.030 (-0.720)	-0.020 (-0.520)
	Education level of household head 1	0.010 (0.180)	0.090 (1.220)	-0.060 (-0.820)	-0.010 (-0.290)	0.010 (-0.040)
	Education level of	-0.060	0.100	-0.090	-0.020	-0.030

	household head 2	(-0.990)	(1.450)	(-1.240)	(-0.540)	(-1.030)
	Education level of household head 3	-0.110 (-1.850)	0.070 (1.040)	-0.150 (-2.010) *	-0.060 (-1.470)	-0.080 (-2.350) ***
	Education level of household head 4	0.030 (0.820)	-0.030 (-0.810)	-0.010 (-0.360)	-0.020 (-0.960)	-0.010 (-0.360)
	Education level of household head 5	-0.060 (-0.750)	-0.140 (-2.190) **	-0.040 (-0.620)	-0.090 (-2.250) **	-0.070 (-2.20) **
	Annual income 1	0.010 (0.150)	-0.030 (-0.590)	0.080 (1.020)	0.030 (0.690)	0.020 (0.670)
	Annual income 2	0.040 (0.470)	0.010 (0.100)	0.100 (1.390)	0.050 (1.100)	0.050 (1.330)
	Annual income 3	-0.090 (-3.610) ***	-0.080 (-3.410) ***	-0.090 (-3.850) ***	-0.080 (-5.550) ***	-0.090 (-7.030) ***
	Annual income 4	-0.060 (-2.640) ***	-0.030 (-1.590)	-0.060 (-3.530) ***	-0.050 (-3.940) ***	-0.050 (-5.010) ***
	Annual income 5	-0.030 (-1.260)	-0.030 (-1.980) *	-0.060 (-3.910) ***	-0.050 (-4.270) ***	-0.040 (-4.550) ***
	Origin as rural	0.040 (1.470)	0.070 (2.840) ***	0.020 (0.750)	0.040 (2.800) ***	0.040 (3.410) ***
Demographics in chicken equation	Constant	-0.020 (-0.90)	-0.010 (-0.330)	0.020 (1.160)	0.010 (0.640)	0.010 (0.230)
	Region1	0.010 (-0.110)	0.060 (2.700) ***	0.040 (1.700)	0.050 (3.450) ***	0.030 (2.870) ***
	Region2	0.010 (0.030)	0.010 (0.600)	-0.030 (-1.410)	-0.010 (-0.50)	0.010 (-0.340)
	Region3	-0.020 (-0.660)	0.020 (0.730)	0.080 (2.720) ***	0.050 (2.900) ***	0.030 (2.100) *
	Region4	0.040 (1.020)	0.050 (1.550)	0.080 (2.850) ***	0.060 (3.240) ***	0.060 (3.460) ***
	Region5	-0.050 (-1.640)	-0.030 (-0.950)	0.020 (0.70)	-0.010 (-0.40)	-0.020 (-1.250)
	household size1	0.010 (0.340)	-0.050 (-1.780)	0.020 (0.770)	-0.010 (-0.750)	-0.010 (-0.420)
	household size2	0.040 (1.220)	0.020 (0.680)	0.020 (0.830)	0.020 (1.170)	0.030 (1.920) *
	household size3	-0.020 (-0.560)	-0.050 (-1.860)	0.010 (0.350)	-0.020 (-1.130)	-0.020 (-1.390)
	household size4	0.020 (0.930)	-0.010 (-0.910)	-0.020 (-1.540)	-0.020 (-1.790)	-0.010 (-1.090)
	age and presence of children 1	-1.090 (-2.190) **	0.100 (0.380)	-0.090 (-0.620)	-0.240 (-3.810) ***	-0.230 (-4.530) ***
	age and presence of children 2	-0.040 (-0.440)	-0.010 (-0.060)	0.450 (4.910) ***	-0.050 (-2.940) ***	-0.030 (-2.210) **

	age and presence of children 3	0.070 (1.240)	-0.050 (-0.830)	0.240 (4.360) ***	-0.060 (-5.490) ***	-0.030 (-3.430) ***
	age and presence of children 6	0.060 (1.210)	-0.050 (-1.040)	-0.170 (-6.290) ***	-0.030 (-2.870) ***	-0.020 (-1.650)
	age of household head 1	0.070 (1.530)	-0.040 (-0.850)	0.200 (4.660) ***	-0.020 (-1.270)	-0.010 (-0.960)
	age of household head 3	0.150 (2.170) *	-0.130 (-2.950) ***	0.330 (5.280) ***	-0.050 (-3.390) ***	-0.030 (-2.590) ***
	age of household head 4	0.080 (1.620)	0.010 (0.080)	0.160 (4.140) ***	0.100 (3.510) ***	0.090 (3.940) ***
	Education level of household head 1	0.080 (1.780)	0.010 (0.170)	0.150 (3.970) ***	0.100 (3.530) ***	0.090 (4.090) ***
	Education level of household head 2	0.100 (2.180) **	-0.010 (-0.150)	0.180 (5.080) ***	0.100 (4.060) ***	0.100 (4.860) ***
	Education level of household head 3	0.090 (1.800)	0.010 (0.240)	0.110 (2.910) ***	0.080 (2.920) ***	0.080 (3.760) ***
	Education level of household head 4	0.010 (0.440)	-0.020 (-0.660)	0.040 (1.340)	0.010 (0.470)	0.010 (0.650)
	Education level of household head 5	0.060 (0.810)	0.100 (1.200)	0.090 (1.340)	0.100 (2.150) *	0.080 (2.300) **
	Annual income 1	-0.020 (-0.350)	0.030 (0.480)	-0.110 (-2.980) ***	-0.050 (-1.660)	-0.040 (-1.780)
	Annual income 2	0.060 (0.960)	-0.060 (-1.180)	-0.120 (-2.860) ***	-0.090 (-2.950) ***	-0.040 (-1.760)
	Annual income 3	0.040 (1.650)	0.060 (2.710) ***	0.010 (-0.060)	0.030 (2.410) ***	0.030 (3.030) ***
	Annual income 4	0.010 (0.770)	0.020 (1.030)	0.010 (-0.100)	0.010 (0.830)	0.010 (1.140)
	Annual income 5	0.010 (-0.100)	0.020 (1.670)	0.020 (1.380)	0.020 (2.250) **	0.010 (1.930) *
	Origin as rural	0.010 (0.120)	-0.050 (-2.680) ***	-0.020 (-1.060)	-0.040 (-3.270) ***	-0.030 (-30.000) ***
Demographics in turkey equation	Constant	-0.010 (-0.430)	-0.010 (-0.620)	-0.010 (-0.350)	-0.010 (-0.880)	-0.010 (-1.240)
	Region1	0.020 (1.140)	-0.040 (-2.240) **	-0.010 (-0.810)	-0.030 (-2.470) ***	-0.020 (-1.540)
	Region2	0.010 (0.670)	-0.030 (-1.850)	0.010 (0.420)	-0.010 (-1.210)	-0.010 (-0.750)
	Region3	0.020 (0.710)	-0.080 (-3.440)	-0.010 (-0.380)	-0.050 (-3.140)	-0.020 (-2.090)

			***		***	*
	Region4	-0.030 (-1.350)	-0.020 (-0.770)	-0.060 (-2.440) ***	-0.040 (-2.450) ***	-0.030 (-2.710) ***
	Region5	0.010 (0.300)	0.020 (0.960)	-0.060 (-2.740) ***	-0.020 (-1.180)	-0.010 (-0.800)
	household size1	0.010 (0.550)	0.010 (0.040)	-0.070 (-3.120) ***	-0.030 (-2.430) ***	-0.020 (-1.760)
	household size2	0.010 (-0.220)	-0.030 (-1.650)	-0.050 (-2.150) *	-0.040 (-2.920) ***	-0.030 (-2.810) ***
	household size3	0.010 (0.610)	0.010 (0.470)	-0.030 (-1.550)	-0.010 (-0.870)	-0.010 (-0.450)
	household size4	-0.030 (-2.160) *	-0.020 (-1.940) *	-0.020 (-2.110) *	-0.020 (-3.060) ***	-0.030 (-4.140) ***
	age and presence of children 1	-0.230 (-0.300)	-0.760 (-2.450) ***	-0.400 (-2.200) **	-0.280 (-2.330) **	-0.240 (-2.800) ***
	age and presence of children 2	0.300 (2.240) **	-0.020 (-0.180)	-0.750 (-5.860) ***	-0.110 (-3.580) ***	-0.080 (-30.000) ***
	age and presence of children 3	0.130 (1.360)	-0.070 (-1.060)	-0.510 (-6.520) ***	-0.090 (-4.980) ***	-0.070 (-4.590) ***
	age and presence of children 6	0.170 (2.420) ***	0.110 (2.090) *	0.110 (2.820) ***	-0.020 (-1.250)	-0.010 (-0.590)
	age of household head 1	0.080 (1.120)	0.070 (1.610)	-0.330 (-5.650) ***	-0.010 (-0.450)	0.010 (0.570)
	age of household head 3	-0.130 (-1.130)	0.050 (0.980)	-0.450 (-5.160) ***	0.010 (0.460)	0.010 (-0.040)
	age of household head 4	0.010 (-0.050)	-0.050 (-0.730)	-0.040 (-0.510)	-0.030 (-0.730)	-0.020 (-0.560)
	Education level of household head 1	0.020 (0.210)	-0.050 (-0.80)	-0.030 (-0.450)	-0.030 (-0.730)	-0.020 (-0.520)
	Education level of household head 2	0.010 (0.180)	-0.030 (-0.420)	-0.040 (-0.510)	-0.020 (-0.510)	-0.010 (-0.290)
	Education level of household head 3	0.050 (0.740)	-0.010 (-0.230)	0.020 (0.240)	0.010 (0.110)	0.020 (0.530)
	Education level of household head 4	0.010 (0.070)	0.010 (-0.110)	0.020 (0.740)	0.010 (0.560)	0.010 (0.630)
	Education level of household head 5	-0.050 (-0.820)	-0.010 (-0.160)	0.040 (0.750)	0.010 (0.210)	-0.010 (-0.270)
	Annual income 1	-0.010 (-0.180)	0.010 (0.180)	-0.020 (-0.310)	0.010 (-0.100)	0.010 (-0.150)
	Annual income 2	0.030 (0.450)	-0.030 (-0.360)	0.010 (0.140)	-0.010 (-0.240)	0.010 (0.20)
	Annual income 3	0.030 (1.090)	0.010 (0.460)	0.020 (0.940)	0.010 (0.970)	0.020 (1.310)
	Annual income 4	0.040	0.030	0.040	0.030	0.030

		(1.710)	(1.300)	(2.050) *	(2.360) ***	(2.950) ***
	Annual income 5	0.010 (0.460)	0.010 (0.200)	0.030 (1.670)	0.010 (1.350)	0.010 (1.490)
	Origin as rural	-0.070 (-2.430) ***	0.080 (3.300) ***	-0.010 (-0.460)	0.030 (2.290) **	0.010 (0.400)
Beef, pork, chicken, turkey equations	Beef price*seafood price	-0.010 (-0.330)	0.040 (1.610)	-0.050 (-2.310) **	0.010 (-0.290)	-0.010 (-0.570)
	Chicken price*seafood price	-0.030 (-10.000)	0.010 (0.550)	-0.030 (-1.290)	-0.010 (-0.370)	-0.010 (-1.120)
	Turkey price*seafood price	0.010 (-0.110)	0.060 (3.050) ***	0.010 (-0.240)	0.030 (2.150) *	0.020 (1.840)
	Seafood price*seafood price	0.010 (0.050)	0.050 (1.720)	-0.040 (-1.390)	0.010 (0.410)	0.010 (0.330)
	Beef price*turkey price	-0.060 (-1.670)	-0.080 (-2.870) ***	-0.070 (-2.440) ***	-0.080 (-4.280) ***	-0.080 (-4.760) ***
	Chicken price*turkey price	0.030 (0.860)	-0.040 (-1.550)	-0.020 (-0.630)	-0.040 (-1.980) *	-0.020 (-1.190)
	Turkey price*turkey price	-0.040 (-1.490)	-0.020 (-0.590)	-0.040 (-1.540)	-0.030 (-1.910) *	-0.040 (-2.450) ***
	Beef price*chicken price	-0.030 (-0.990)	-0.020 (-0.730)	-0.020 (-0.680)	-0.020 (-1.280)	-0.030 (-1.810)
	Chicken price*chicken price	-0.050 (-1.620)	0.010 (0.390)	0.010 (0.560)	0.010 (0.550)	-0.010 (-0.490)
	Beef price*beef price	0.020 (1.110)	0.040 (2.500) ***	0.070 (4.940) ***	0.060 (5.540) ***	0.050 (5.610) ***
	Lagged beef disappearance	-0.060 (-16.660) ***	-0.090 (-25.820) ***	-0.090 (-25.870) ***	-0.090 (-37.950) ***	-0.080 (-41.510) ***
	Lagged pork disappearance	-0.070 (-18.790) ***	-0.10 (-26.440) ***	-0.080 (-26.650) ***	-0.090 (-38.540) ***	-0.080 (-43.310) ***
	Lagged chicken disappearance	-0.030 (-13.740) ***	-0.050 (-21.930) ***	-0.050 (-23.580) ***	-0.050 (-33.250) ***	-0.040 (-36.020) ***
	Lagged turkey disappearance	-0.020 (-13.280) ***	-0.040 (-24.580) ***	-0.030 (-28.260) ***	-0.030 (-38.980) ***	-0.030 (-42.810) ***
	Lagged seafood disappearance	-0.150 (-16.960) ***	-0.160 (-24.680) ***	-0.160 (-24.380) ***	-0.150 (-36.130) ***	-0.150 (-41.660) ***

a: Due to the fact that the models based on period 2002-2003,2004-2005 and 2006-2007 have high multi-collinearity among estimated parameters, the parameter significance may not be reliable. Therefore, we use the models based on 2002-2007 and 2004-2007 to evaluate the significance of parameters.
b: ”*,**,***” represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses.

Table C.7 Estimation of Demand System Based on Yearly Panel Data and Predictive Difference Approach-Group 3 ("Somewhat Concerned Group")

Equation	Variable	2002-2003[a]	2004-2005	2006-2007	2004-2007	2002-2007
Total Meat expenditure equation	Constant[b]	4.140 (2.100) *	1.360 (1.130)	2.230 (1.800)	2.090 (2.880) ***	2.760 (4.170) ***
	Region1	0.160 (0.510)	0.260 (1.350)	0.480 (1.690)	0.370 (2.860) ***	0.380 (3.520) ***
	Region2	-0.050 (-0.20)	0.120 (0.760)	0.430 (2.430) ***	0.280 (2.740) ***	0.210 (2.390) ***
	Region3	-0.230 (-0.990)	0.140 (0.850)	0.200 (1.220)	0.170 (1.660)	0.090 (1.040)
	Region4	-0.640 (-2.140) *	-0.010 (-0.070)	-0.090 (-0.570)	-0.060 (-0.640)	-0.210 (-2.390) ***
	Region5	0.030 (0.080)	0.020 (0.120)	0.280 (1.300)	0.140 (1.260)	0.120 (1.200)
	household size1	-1.260 (-1.520)	-0.640 (-1.790)	-0.630 (-1.290)	-0.640 (-2.680) ***	-0.970 (-4.340) ***
	household size2	-0.580 (-0.730)	-0.320 (-0.930)	-0.300 (-0.630)	-0.300 (-1.320)	-0.460 (-2.140) *
	household size3	-0.560 (-0.710)	-0.240 (-0.770)	-0.220 (-0.450)	-0.230 (-0.990)	-0.400 (-1.820)
	household size4	-0.210 (-0.280)	-0.060 (-0.230)	-0.290 (-0.620)	-0.180 (-0.850)	-0.220 (-1.10)
	age and presence of children 1	0.270 (0.740)	-0.020 (-0.090)	0.180 (0.830)	0.080 (0.590)	0.110 (0.990)
	age and presence of children 2	0.550 (0.670)	0.260 (0.390)	0.270 (0.460)	0.270 (0.680)	0.410 (1.230)
	age and presence of children 3	0.470 (0.770)	0.150 (0.420)	0.350 (0.750)	0.280 (1.250)	0.350 (1.830)
	age and presence of children 6	0.700 (1.100)	0.270 (0.480)	0.430 (0.700)	0.360 (0.990)	0.510 (1.880)
	age of household head 1	-0.690 (-2.660) ***	-0.220 (-1.360)	-0.280 (-1.910) *	-0.260 (-2.670) ***	-0.420 (-4.910) ***
	age of household head 3	-0.180 (-0.850)	0.060 (0.400)	-0.010 (-0.070)	0.010 (0.150)	-0.010 (-0.140)
	age of household head 4	-0.150 (-0.650)	0.110 (0.700)	0.030 (0.190)	0.070 (0.660)	0.040 (0.420)
	Education level of household head 1	0.070 (0.240)	0.320 (1.480)	0.270 (1.140)	0.300 (2.080) *	0.290 (2.480) ***
	Education level of household head 2	0.030 (0.090)	0.170 (0.980)	0.160 (0.980)	0.170 (1.60)	0.160 (1.720)
	Education level of household head 3	0.010 (0.030)	0.160 (0.910)	0.160 (0.950)	0.160 (1.550)	0.150 (1.660)
	Education level of	0.030	0.130	0.060	0.100	0.110

	household head 4	(0.130)	(0.900)	(0.400)	(1.120)	(1.320)
	Education level of household head 5	0.050 (0.140)	0.250 (0.950)	0.180 (0.660)	0.210 (1.230)	0.200 (1.510)
	Annual income 1	-0.170 (-0.470)	-0.280 (-1.360)	-0.380 (-1.720)	-0.330 (-2.620) ***	-0.350 (-3.140) ***
	Annual income 2	-0.110 (-0.320)	-0.110 (-0.610)	-0.380 (-1.820)	-0.250 (-2.150) *	-0.260 (-2.560) ***
	Annual income 3	-0.160 (-0.660)	0.060 (0.400)	-0.190 (-1.030)	-0.080 (-0.730)	-0.100 (-1.160)
	Annual income 4	0.180 (0.620)	0.120 (0.610)	0.020 (0.110)	0.070 (0.530)	0.110 (1.120)
	Annual income 5	-0.110 (-0.560)	0.100 (0.590)	0.010 (-0.020)	0.050 (0.410)	0.010 (0.130)
	Origin as rural	-0.200 (-1.130)	-0.110 (-1.120)	-0.080 (-0.630)	-0.100 (-1.380)	-0.150 (-2.530) ***
	Stone price index	0.700 (0.760)	0.430 (0.80)	0.180 (0.310)	0.180 (0.520)	0.500 (1.640)
	Lagged meat expenditure	0.160 (9.370) ***	0.590 (38.460) ***	0.550 (33.040) ***	0.560 (57.60) ***	0.370 (53.990) ***
Demographics in beef equation	Constant	0.840 (1.20)	-0.040 (-0.140)	0.250 (0.890)	0.220 (2.110) *	0.030 (0.320)
	Region1	0.150 (0.250)	-0.350 (-1.070)	0.900 (4.260) ***	0.020 (0.200)	0.060 (0.860)
	Region2	-0.370 (-1.210)	-0.080 (-0.600)	-0.030 (-0.360)	-0.130 (-2.680) ***	-0.050 (-1.320)
	Region3	-0.620 (-2.80) ***	0.320 (2.770) ***	-1.220 (-8.520) ***	-0.370 (-7.690) ***	-0.220 (-6.160) ***
	Region4	-0.660 (-0.680)	0.730 (2.230) **	-0.130 (-0.270)	0.080 (0.760)	0.070 (0.730)
	Region5	1.420 (1.350)	0.360 (1.170)	-0.250 (-0.980)	0.020 (0.220)	-0.030 (-0.410)
	household size1	-0.140 (-0.180)	-0.340 (-2.280) **	-0.220 (-20.000) *	-0.180 (-3.710) ***	-0.120 (-2.950) ***
	household size2	-4.950 (-1.050)	-2.350 (-2.660) ***	-0.410 (-0.300)	-0.320 (-1.010)	0.600 (2.510) ***
	household size3	0.800 (0.240)	2.900 (2.910) ***	-0.570 (-0.820)	0.400 (1.390)	-0.530 (-2.490) ***
	household size4	12.140 (1.130)	1.140 (0.840)	0.930 (0.320)	0.180 (0.450)	-0.640 (-1.940) *
	age and presence of children 1	0.880 (1.510)	0.080 (0.390)	-0.340 (-2.330) **	-0.080 (-0.970)	-0.150 (-2.360) ***

	age and presence of children 2	-0.090 (-0.960)	-0.030 (-0.380)	-0.010 (-0.200)	-0.070 (-3.460) ***	-0.040 (-2.480) ***
	age and presence of children 3	0.010 (0.020)	0.070 (1.620)	0.040 (1.040)	0.030 (1.420)	0.030 (1.780)
	age and presence of children 6	-0.120 (-1.580)	-0.020 (-0.480)	-0.030 (-1.280)	-0.050 (-3.440) ***	-0.030 (-2.870) ***
	age of household head 1	-0.050 (-0.590)	0.020 (0.620)	-0.010 (-0.220)	-0.020 (-1.420)	-0.010 (-1.020)
	age of household head 3	-0.060 (-0.700)	0.090 (2.460) ***	0.030 (0.970)	0.030 (1.790)	0.010 (1.160)
	age of household head 4	0.020 (0.110)	-0.030 (-0.290)	-0.050 (-0.500)	-0.030 (-0.540)	-0.020 (-0.460)
	Education level of household head 1	0.030 (0.240)	-0.010 (-0.120)	-0.020 (-0.200)	-0.010 (-0.180)	0.010 (0.080)
	Education level of household head 2	0.050 (0.340)	-0.050 (-0.550)	-0.030 (-0.310)	-0.030 (-0.620)	-0.010 (-0.190)
	Education level of household head 3	0.050 (0.350)	-0.040 (-0.490)	-0.050 (-0.580)	-0.050 (-0.80)	-0.010 (-0.190)
	Education level of household head 4	0.030 (0.690)	0.030 (0.750)	0.050 (1.530)	0.040 (1.910) *	0.030 (1.580)
	Education level of household head 5	-0.010 (-0.160)	0.050 (0.580)	0.040 (0.400)	0.050 (0.810)	0.030 (0.850)
	Annual income 1	0.040 (0.500)	-0.010 (-0.160)	0.060 (0.990)	0.020 (0.630)	0.030 (0.930)
	Annual income 2	-0.010 (-0.140)	0.010 (0.130)	-0.050 (-1.090)	-0.010 (-0.250)	-0.020 (-0.620)
	Annual income 3	0.030 (0.940)	0.010 (0.630)	0.020 (1.070)	0.020 (1.400)	0.020 (1.660)
	Annual income 4	0.020 (1.010)	0.010 (-0.170)	0.010 (0.530)	0.010 (0.240)	0.010 (1.010)
	Annual income 5	0.010 (0.190)	-0.010 (-0.920)	0.010 (-0.290)	-0.010 (-1.010)	-0.010 (-0.910)
	Origin as rural	0.030 (1.120)	-0.020 (-0.850)	0.010 (0.120)	-0.010 (-0.450)	0.010 (0.570)
Demographics in pork equation	Constant	0.010 (0.430)	0.010 (0.710)	0.010 (-0.130)	0.010 (0.640)	0.010 (1.100)
	region1	0.050 (1.930) *	0.030 (1.460)	0.050 (1.830)	0.040 (2.730) ***	0.040 (3.770) ***
	region2	0.060 (2.470) ***	-0.030 (-1.490)	-0.010 (-0.800)	-0.020 (-1.620)	0.010 (0.590)
	region3	0.020 (0.560)	-0.030 (-1.070)	0.010 (-0.040)	-0.010 (-0.860)	-0.010 (-0.490)
	region4	0.060 (1.720)	0.010 (0.420)	0.050 (1.800)	0.030 (1.810)	0.040 (3.200) ***
	region5	0.020 (0.620)	0.010 (0.120)	0.010 (0.300)	0.010 (0.310)	0.010 (10.000)
	household size1	-0.010 (-0.380)	-0.020 (-0.900)	0.020 (0.990)	0.010 (-0.020)	0.010 (0.010)

	household size2	-0.010 (-0.310)	-0.040 (-1.640)	-0.070 (-4.440) ***	-0.050 (-4.550) ***	-0.030 (-3.690) ***
	household size3	-0.010 (-0.450)	-0.030 (-1.500)	-0.040 (-2.440) ***	-0.030 (-3.100) ***	-0.020 (-2.450) ***
	household size4	-0.010 (-0.800)	0.010 (0.750)	0.010 (0.300)	0.010 (0.850)	0.010 (0.010)
	age and presence of children 1	0.410 (0.270)	1.580 (3.430) ***	-1.410 (-5.060) ***	-0.210 (-1.310)	-0.70 (-6.050) ***
	age and presence of children 2	0.100 (0.420)	0.240 (1.270)	0.280 (2.490) ***	0.140 (3.490) ***	0.040 (1.330)
	age and presence of children 3	-0.180 (-0.770)	0.070 (0.620)	0.030 (0.370)	0.030 (1.220)	-0.010 (-0.590)
	age and presence of children 6	0.020 (0.160)	-0.100 (-1.180)	0.110 (2.450) ***	0.060 (2.300) **	0.080 (4.490) ***
	age of household head 1	-0.200 (-1.540)	0.010 (0.210)	0.040 (0.660)	0.020 (0.980)	0.010 (-0.060)
	age of household head 3	-0.400 (-2.290) **	0.050 (0.830)	0.010 (-0.020)	0.040 (1.620)	-0.010 (-0.490)
	age of household head 4	0.100 (0.560)	0.080 (0.640)	0.010 (0.100)	0.060 (0.850)	0.060 (1.150)
	Education level of household head 1	0.070 (0.420)	0.080 (0.670)	0.040 (0.320)	0.070 (1.050)	0.060 (1.210)
	Education level of household head 2	0.040 (0.230)	0.050 (0.440)	0.010 (0.090)	0.050 (0.750)	0.040 (0.770)
	Education level of household head 3	0.110 (0.650)	0.080 (0.710)	0.090 (0.790)	0.100 (1.550)	0.090 (1.750)
	Education level of household head 4	-0.120 (-1.370)	-0.020 (-0.340)	-0.120 (-2.900) ***	-0.050 (-1.890) *	-0.070 (-2.760) ***
	Education level of household head 5	-0.230 (-1.60)	-0.100 (-1.030)	-0.090 (-1.140)	-0.100 (-1.980) *	-0.120 (-2.980) ***
	Annual income 1	-0.020 (-0.110)	0.180 (1.980) *	-0.320 (-3.770) ***	-0.060 (-1.300)	-0.020 (-0.590)
	Annual income 2	-0.120 (-0.740)	0.030 (0.180)	0.020 (0.120)	0.030 (0.330)	0.010 (-0.070)
	Annual income 3	0.060 (1.240)	-0.110 (-3.670) ***	-0.090 (-2.850) ***	-0.100 (-5.250) ***	-0.060 (-4.140) ***
	Annual income 4	0.010 (-0.040)	-0.120 (-3.830) ***	-0.070 (-1.960) *	-0.090 (-4.810) ***	-0.070 (-4.430) ***
	Annual income 5	-0.040 (-1.050)	-0.010 (-0.300)	-0.020 (-0.590)	-0.010 (-0.820)	-0.020 (-1.560)
	Origin as rural	0.120 (2.140) *	0.050 (1.140)	0.060 (1.140)	0.050 (1.640)	0.070 (2.950) ***
Demograp	Constant	0.040	0.050	0.040	0.030	0.040

hics in chicken equation		(0.850)	(1.330)	(0.960)	(1.520)	(1.960) *
	region1	0.010 (0.230)	0.010 (0.400)	-0.010 (-0.250)	0.010 (0.160)	0.010 (0.320)
	region2	0.010 (-0.030)	0.040 (1.240)	0.080 (2.130) *	0.050 (2.570) ***	0.030 (1.980) *
	region3	0.160 (2.120) *	0.020 (0.430)	0.100 (1.810)	0.060 (1.790)	0.080 (2.910) ***
	region4	-0.040 (-0.690)	0.020 (0.500)	0.040 (0.770)	0.030 (1.030)	0.010 (0.350)
	region5	-0.030 (-0.540)	-0.080 (-2.110) *	0.010 (-0.090)	-0.040 (-1.690)	-0.050 (-2.200) **
	household size1	-0.050 (-0.990)	-0.130 (-3.450) ***	0.010 (0.050)	-0.060 (-2.600) ***	-0.060 (-3.020) ***
	household size2	-0.060 (-1.060)	0.020 (0.570)	0.040 (0.950)	0.030 (1.150)	0.010 (0.030)
	household size3	-0.060 (-1.160)	-0.030 (-0.720)	0.030 (0.760)	0.010 (-0.050)	-0.020 (-1.180)
	household size4	0.050 (1.450)	-0.020 (-0.740)	0.030 (1.250)	0.010 (0.540)	0.020 (1.420)
	age and presence of children 1	0.170 (0.110)	-1.160 (-2.900) ***	0.330 (1.220)	-0.310 (-2.610) ***	-0.300 (-3.280) ***
	age and presence of children 2	0.330 (1.480)	0.040 (0.230)	-0.010 (-0.080)	0.080 (2.480) ***	0.070 (2.860) ***
	age and presence of children 3	0.160 (0.890)	0.010 (0.110)	0.010 (-0.040)	0.010 (-0.050)	0.010 (0.450)
	age and presence of children 6	0.100 (0.600)	0.100 (1.230)	0.010 (0.020)	0.030 (1.540)	0.020 (1.180)
	age of household head 1	0.010 (0.010)	0.020 (0.240)	0.050 (0.630)	0.020 (1.060)	0.010 (0.550)
	age of household head 3	-0.110 (-0.510)	-0.030 (-0.410)	0.030 (0.230)	-0.020 (-1.020)	0.010 (-0.140)
	age of household head 4	0.030 (0.210)	0.150 (1.120)	0.030 (0.220)	0.070 (0.830)	0.060 (0.980)
	Education level of household head 1	-0.050 (-0.320)	0.100 (0.780)	0.030 (0.250)	0.050 (0.620)	0.030 (0.440)
	Education level of household head 2	-0.010 (-0.040)	0.110 (0.850)	0.080 (0.710)	0.080 (10.000)	0.060 (10.000)
	Education level of household head 3	0.010 (0.010)	0.070 (0.600)	0.060 (0.520)	0.050 (0.680)	0.040 (0.600)
	Education level of household head 4	-0.010 (-0.150)	0.020 (0.430)	0.030 (0.580)	0.020 (0.530)	0.010 (0.560)
	Education level of household head 5	-0.060 (-0.480)	0.050 (0.780)	-0.090 (-0.710)	-0.020 (-0.570)	-0.040 (-1.230)
	Annual income 1	0.040 (0.210)	0.030 (0.370)	0.010 (0.080)	0.020 (0.320)	0.020 (0.420)
	Annual income 2	0.010 (0.030)	0.010 (0.030)	-0.010 (-0.060)	-0.010 (-0.140)	-0.010 (-0.140)
	Annual income 3	0.010	0.020	0.040	0.030	0.030

		(0.020)	(0.780)	(1.210)	(1.800)	(2.170) *
	Annual income 4	0.020 (0.570)	0.030 (1.110)	0.010 (0.120)	0.020 (1.070)	0.020 (1.440)
	Annual income 5	0.010 (-0.080)	-0.020 (-0.810)	0.010 (0.180)	-0.010 (-0.390)	0.010 (-0.190)
	Origin as rural	-0.060 (-1.150)	0.030 (0.780)	-0.060 (-1.510)	-0.020 (-0.990)	-0.030 (-1.590)
Demographics in turkey equation	Constant	-0.060 (-1.310)	0.010 (0.370)	-0.070 (-2.100) *	-0.030 (-1.560)	-0.040 (-2.230) **
	region1	0.020 (0.390)	-0.010 (-0.200)	-0.050 (-1.240)	-0.030 (-1.370)	-0.020 (-0.980)
	region2	0.010 (0.040)	0.010 (0.170)	-0.090 (-2.610) ***	-0.040 (-2.040) *	-0.030 (-1.650)
	region3	-0.020 (-0.320)	0.040 (1.010)	-0.090 (-2.300) **	-0.030 (-1.130)	-0.020 (-1.200)
	region4	-0.010 (-0.250)	-0.100 (-2.630) ***	0.010 (0.100)	-0.040 (-1.850)	-0.040 (-1.930) *
	region5	-0.030 (-0.760)	-0.050 (-1.570)	0.010 (0.010)	-0.020 (-0.880)	-0.020 (-1.120)
	household size1	0.060 (1.310)	-0.010 (-0.420)	-0.040 (-1.100)	-0.020 (-0.980)	0.010 (-0.050)
	household size2	0.010 (0.270)	-0.020 (-0.610)	-0.040 (-0.970)	-0.020 (-1.010)	-0.010 (-0.760)
	household size3	0.010 (0.300)	0.020 (0.500)	-0.020 (-0.460)	0.010 (0.320)	0.010 (0.530)
	household size4	-0.010 (-0.400)	0.010 (-0.040)	-0.010 (-0.620)	-0.010 (-0.650)	-0.010 (-0.750)
	age and presence of children 1	-2.800 (-1.250)	-0.780 (-1.690)	-0.520 (-1.620)	-0.370 (-1.980) *	0.160 (1.140)
	age and presence of children 2	-0.150 (-0.40)	-0.450 (-2.620) ***	-0.050 (-0.190)	-0.10 (-2.050) *	-0.050 (-1.20)
	age and presence of children 3	0.060 (0.530)	-0.300 (-3.150) ***	-0.100 (-0.680)	-0.090 (-2.940) ***	-0.050 (-1.860)
	age and presence of children 6	0.070 (0.430)	-0.140 (-1.790)	-0.050 (-0.730)	-0.050 (-1.700)	-0.080 (-3.800) ***
	age of household head 1	0.310 (1.900) *	-0.060 (-1.010)	-0.040 (-0.400)	0.010 (0.530)	0.040 (1.670)
	age of household head 3	0.530 (1.480)	-0.140 (-2.010) *	-0.030 (-0.210)	-0.020 (-0.770)	0.020 (0.770)
	age of household head 4	-0.130 (-0.550)	-0.160 (-1.020)	0.010 (0.100)	-0.070 (-0.780)	-0.080 (-1.140)
	Education level of household head 1	-0.010 (-0.050)	-0.040 (-0.270)	0.020 (0.180)	-0.010 (-0.150)	-0.020 (-0.260)
	Education level of	-0.030	-0.060	0.040	-0.020	-0.020

	household head 2	(-0.160)	(-0.410)	(0.300)	(-0.180)	(-0.350)
	Education level of household head 3	-0.140 (-0.660)	-0.060 (-0.380)	-0.040 (-0.300)	-0.040 (-0.490)	-0.070 (-1.040)
	Education level of household head 4	0.080 (10.000)	-0.030 (-0.510)	0.050 (0.990)	0.010 (0.280)	0.030 (1.110)
	Education level of household head 5	0.190 (0.840)	-0.150 (-1.240)	-0.030 (-0.260)	-0.090 (-1.350)	-0.010 (-0.200)
	Annual income 1	-0.070 (-0.540)	-0.140 (-1.570)	0.040 (0.310)	-0.060 (-1.060)	-0.070 (-1.570)
	Annual income 2	0.050 (0.240)	-0.090 (-0.510)	-0.010 (-0.100)	-0.060 (-0.680)	-0.020 (-0.290)
	Annual income 3	0.030 (0.710)	0.090 (2.640) ***	0.020 (0.620)	0.050 (2.540) ***	0.050 (30.000) ***
	Annual income 4	0.050 (1.130)	0.080 (2.270) **	-0.030 (-0.880)	0.030 (1.470)	0.030 (1.920) *
	Annual income 5	0.110 (2.520) ***	0.040 (1.350)	-0.020 (-0.650)	0.010 (0.470)	0.030 (2.210) **
	Origin as rural	-0.090 (-1.400)	-0.090 (-1.950) *	-0.130 (-2.670) ***	-0.110 (-3.690) ***	-0.100 (-4.300) ***
Beef, pork, chicken, turkey equations	Beef price*seafood price	-0.060 (-1.190)	-0.100 (-2.460) ***	-0.060 (-1.600)	-0.080 (-3.340) ***	-0.070 (-3.700) ***
	Chicken price*seafood price	-0.120 (-2.080) *	-0.020 (-0.540)	-0.080 (-20.000) *	-0.050 (-2.170) *	-0.070 (-3.300) ***
	Turkey price*seafood price	-0.10 (-2.020) *	-0.030 (-0.700)	-0.070 (-1.780)	-0.050 (-2.230) **	-0.060 (-3.160) ***
	Seafood price*seafood price	-0.210 (-3.080) ***	-0.150 (-3.170) ***	-0.050 (-1.110)	-0.100 (-3.560) ***	-0.110 (-4.910) ***
	Beef price*turkey price	0.020 (0.310)	0.070 (1.680)	-0.040 (-0.950)	0.010 (0.520)	0.010 (0.490)
	Chicken price*turkey price	0.040 (0.660)	0.010 (0.340)	-0.030 (-0.780)	-0.010 (-0.460)	0.010 (-0.230)
	Turkey price*turkey price	-0.010 (-0.260)	0.020 (0.490)	0.010 (0.010)	0.010 (0.300)	0.010 (-0.110)
	Beef price*chicken price	0.010 (0.180)	-0.050 (-1.390)	0.020 (0.480)	-0.020 (-0.680)	-0.020 (-0.820)
	Chicken price*chicken price	0.060 (1.080)	-0.040 (-1.030)	0.010 (-0.080)	-0.030 (-1.040)	-0.010 (-0.410)
	Beef price*beef price	-0.020 (-0.580)	0.040 (2.030) *	0.010 (0.610)	0.030 (2.170) *	0.020 (1.660)
	Lagged beef disappearance	-0.110 (-12.660) ***	-0.100 (-17.650) ***	-0.120 (-20.060) ***	-0.10 (-28.070) ***	-0.090 (-31.730) ***
	Lagged pork disappearance	-0.110 (-12.790) ***	-0.120 (-17.740) ***	-0.120 (-19.10) ***	-0.110 (-27.490) ***	-0.100 (-31.320) ***
	Lagged chicken	-0.060	-0.060	-0.070	-0.060	-0.050

	disappearance	(-11.980) ***	(-15.320) ***	(-17.860) ***	(-24.670) ***	(-28.330) ***
	Lagged turkey disappearance	-0.040 (-14.100) ***	-0.050 (-20.380) ***	-0.040 (-190.00) ***	-0.040 (-30.480) ***	-0.040 (-35.970) ***
	Lagged seafood disappearance	-0.210 (-11.600) ***	-0.160 (-12.690) ***	-0.150 (-16.320) ***	-0.140 (-22.050) ***	-0.150 (-26.990) ***

a: Due to the fact that the models based on period 2002-2003,2004-2005 and 2006-2007 have high multi-collinearity among estimated parameters, the parameter significance may not be reliable. Therefore, we use the models based on 2002-2007 and 2004-2007 to evaluate the significance of parameters.
b: "*,**,***" represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses.

Table C.8 Estimation of Demand System Based on Yearly Panel Data and Predictive Difference Approach-Group 4 ("Reporting no Beef Eating Group")

Equation	Variable	2002-2003	2004-2005	2006-2007	2004-2007	2002-2007
Total Meat expenditure equation	Constant[b]	11.790 (0.990)	3.430 (0.740)	5.450 (1.240)	4.950 (1.730)	6.030 (2.570) ***
	region1	1.920 (0.700)	0.540 (0.480)	0.730 (0.50)	0.620 (0.950)	1.040 (2.020) *
	region2	1.140 (0.820)	0.020 (0.030)	0.110 (0.170)	0.070 (0.220)	0.320 (1.220)
	region3	1.240 (0.800)	0.120 (0.160)	0.180 (0.320)	0.120 (0.340)	0.390 (1.400)
	region4	0.290 (0.180)	0.130 (0.190)	-0.040 (-0.050)	0.070 (0.190)	0.210 (0.610)
	region5	1.060 (0.590)	-0.090 (-0.100)	0.290 (0.360)	0.040 (0.090)	0.270 (0.720)
	household size1	-0.600 (-0.060)	-1.190 (-0.360)	-0.670 (-0.230)	-1.040 (-0.470)	-0.870 (-0.520)
	household size2	-0.380 (-0.040)	-0.970 (-0.30)	-0.470 (-0.160)	-0.800 (-0.360)	-0.630 (-0.370)
	household size3	-0.710 (-0.080)	-0.130 (-0.040)	-0.360 (-0.120)	-0.310 (-0.140)	-0.210 (-0.120)
	household size4	0.070 (0.010)	-0.460 (-0.130)	-0.020 (-0.010)	-0.300 (-0.150)	-0.120 (-0.070)
	age and presence of children 1	0.540 (0.210)	0.050 (0.030)	0.160 (0.080)	0.050 (0.050)	0.280 (0.370)
	age and presence of children 2	-2.190 (0.010)	-0.20 (0.010)	-1.410 (0.010)	-0.910 (-0.690)	-1.30 (-0.870)
	age and presence of children 3	1.820 (0.010)	0.340 (0.010)	0.990 (0.010)	0.660 (0.090)	1.010 (0.670)
	age and presence of children 6	0.740 (0.010)	-3.310 (0.010)	-2.210 (0.010)	-2.660 (-1.280)	-2.240 (-1.060)
	age of household head 1	-0.450 (-0.230)	-0.520 (-0.720)	-0.460 (-0.610)	-0.540 (-1.380)	-0.490 (-1.430)
	age of household head 3	-0.460 (-0.320)	-0.310 (-0.480)	-0.100 (-0.160)	-0.220 (-0.630)	-0.260 (-0.960)
	age of household	0.080	-0.130	0.330	0.080	0.160

	head 4	(0.070)	(-0.310)	(0.520)	(0.290)	(0.660)
	Education level of household head 1	-0.100 (-0.060)	-0.130 (-0.180)	-0.050 (-0.050)	-0.120 (-0.280)	-0.240 (-0.590)
	Education level of household head 2	0.290 (0.170)	0.060 (0.110)	0.430 (0.690)	0.230 (0.690)	0.210 (0.750)
	Education level of household head 3	0.390 (0.180)	0.720 (0.90)	0.370 (0.420)	0.510 (1.150)	0.410 (1.040)
	Education level of household head 4	-0.330 (-0.220)	0.350 (0.600)	0.040 (0.080)	0.150 (0.490)	0.010 (0.030)
	Education level of household head 5	0.160 (0.090)	0.130 (0.170)	0.310 (0.380)	0.200 (0.480)	0.120 (0.360)
	Annual income 1	-0.840 (-0.440)	-0.500 (-0.510)	-1.090 (-1.040)	-0.830 (-1.490)	-0.890 (-1.990) *
	Annual income 2	-0.560 (-0.280)	-0.380 (-0.360)	0.130 (0.120)	-0.160 (-0.270)	-0.310 (-0.650)
	Annual income 3	-0.590 (-0.230)	-0.640 (-0.680)	-0.600 (-0.540)	-0.630 (-1.130)	-0.660 (-1.400)
	Annual income 4	-0.450 (-0.210)	-0.350 (-0.390)	-0.060 (-0.060)	-0.210 (-0.370)	-0.250 (-0.550)
	Annual income 5	-0.580 (-0.270)	-0.030 (-0.030)	-0.830 (-0.760)	-0.460 (-0.850)	-0.490 (-1.140)
	Origin as rural	0.020 (0.010)	-0.020 (-0.030)	0.320 (0.580)	0.130 (0.470)	0.110 (0.470)
	Stone price index	-4.430 (-1.520)	-0.250 (-0.180)	-1.680 (-1.020)	-1.120 (-1.390)	-1.630 (-2.410) ***
	Lagged meat expenditure	0.280 (2.140) *	0.550 (8.200) ***	0.570 (8.310) ***	0.560 (15.170) ***	0.480 (17.290) ***
Demographics in beef equation	Constant	0.050 (0.020)	0.320 (0.30)	0.310 (0.270)	0.030 (0.120)	0.080 (0.410)
	region1	-1.350 (-0.470)	0.330 (0.360)	-0.710 (-0.840)	0.110 (0.440)	-0.10 (-0.550)
	region2	-0.160 (-0.050)	-0.460 (-0.820)	0.120 (0.270)	-0.020 (-0.150)	0.010 (-0.040)
	region3	1.290 (1.190)	-0.470 (-1.210)	0.010 (-0.010)	-0.140 (-10.000)	0.010 (-0.020)
	region4	12.230 (0.020)	-0.420 (-0.340)	0.760 (0.510)	0.060 (0.190)	-0.070 (-0.280)
	region5	5.020 (0.010)	0.730 (0.620)	-1.030 (-1.130)	-0.490 (-1.450)	-0.330 (-1.250)
	household size1	-11.160 (-0.020)	-0.510 (-0.550)	0.720 (1.370)	0.460 (1.890) *	0.340 (1.670)
	household size2	-9.270 (-0.020)	1.150 (0.470)	-1.020 (-0.240)	0.840 (0.990)	0.300 (0.500)
	household size3	5.180 (0.040)	-3.260 (-1.140)	1.460 (0.600)	-0.290 (-0.330)	0.210 (0.330)
	household size4	-13.650 (-0.060)	-1.190 (-0.330)	2.520 (0.290)	-0.890 (-0.910)	-0.200 (-0.270)
	age and presence of children 1	-3.520 (-0.010)	0.220 (0.190)	0.010 (0.010)	0.020 (0.040)	0.090 (0.190)
	age and presence of children 2	0.010 (0.010)	-0.030 (-0.110)	-0.070 (-0.320)	0.030 (0.320)	0.010 (-0.060)

	age and presence of children 3	1.760 (0.020)	-0.020 (-0.110)	-0.040 (-0.280)	-0.020 (-0.50)	-0.010 (-0.330)
	age and presence of children 6	0.710 (0.010)	-0.060 (-0.410)	0.040 (0.380)	0.010 (0.190)	0.010 (-0.030)
	age of household head 1	1.050 (0.020)	0.020 (0.170)	0.010 (0.060)	0.020 (0.50)	0.010 (0.210)
	age of household head 3	1.520 (0.030)	0.020 (0.140)	-0.090 (-0.650)	-0.030 (-0.650)	0.010 (0.030)
	age of household head 4	-0.330 (-0.080)	0.050 (0.060)	-0.180 (-0.220)	-0.050 (-0.090)	-0.140 (-0.310)
	Education level of household head 1	-0.360 (-0.090)	0.010 (0.010)	-0.210 (-0.250)	-0.080 (-0.150)	-0.170 (-0.390)
	Education level of household head 2	-0.290 (-0.070)	0.020 (0.020)	-0.240 (-0.290)	-0.090 (-0.170)	-0.180 (-0.400)
	Education level of household head 3	-0.750 (-0.190)	-0.080 (-0.090)	-0.300 (-0.320)	-0.190 (-0.410)	-0.310 (-0.720)
	Education level of household head 4	-0.250 (-0.490)	0.150 (0.400)	0.020 (0.030)	0.110 (0.390)	-0.010 (-0.040)
	Education level of household head 5	0.300 (0.010)	0.090 (0.010)	-0.070 (0.010)	0.020 (0.010)	0.050 (0.090)
	Annual income 1	0.410 (0.010)	-0.260 (0.010)	0.330 (0.010)	0.010 (0.010)	0.150 (0.170)
	Annual income 2	0.380 (0.010)	0.20 (0.010)	0.070 (0.010)	0.160 (0.190)	0.170 (0.120)
	Annual income 3	-0.010 (-0.040)	0.010 (0.040)	0.040 (0.240)	0.020 (0.340)	0.020 (0.320)
	Annual income 4	0.070 (0.410)	-0.040 (-0.430)	0.010 (-0.030)	-0.020 (-0.580)	0.010 (0.210)
	Annual income 5	0.060 (0.320)	0.060 (0.560)	0.090 (1.170)	0.070 (1.320)	0.070 (1.690)
	Origin as rural	0.030 (0.080)	0.040 (0.290)	0.030 (0.290)	0.010 (0.240)	0.010 (0.160)
Demographics in pork equation	Constant	-0.040 (-0.180)	-0.030 (-0.360)	-0.060 (-0.730)	-0.040 (-1.040)	-0.040 (-1.330)
	region1	-0.020 (-0.050)	-0.030 (-0.270)	-0.060 (-0.710)	-0.060 (-1.330)	-0.060 (-1.610)
	region2	-0.020 (-0.120)	0.030 (0.270)	0.010 (0.10)	0.020 (0.30)	0.010 (0.040)
	region3	0.010 (0.020)	-0.060 (-0.660)	-0.030 (-0.270)	-0.050 (-1.090)	-0.040 (-1.140)
	region4	-0.030 (-0.070)	-0.060 (-0.480)	-0.050 (-0.350)	-0.040 (-0.670)	-0.030 (-0.540)
	region5	-0.030 (-0.130)	-0.100 (-0.870)	0.030 (0.230)	-0.040 (-0.530)	-0.020 (-0.350)
	household size1	-0.120 (-0.420)	-0.120 (-1.060)	-0.060 (-0.440)	-0.080 (-1.140)	-0.080 (-1.560)
	household size2	-0.070 (-0.290)	0.020 (0.170)	0.030 (0.230)	0.040 (0.460)	0.020 (0.370)
	household size3	-0.090 (-0.350)	-0.030 (-0.30)	-0.070 (-0.620)	-0.040 (-0.660)	-0.040 (-0.930)
	household size4	0.040 (0.170)	-0.030 (-0.470)	0.020 (0.240)	0.010 (-0.050)	0.020 (0.680)
	age and presence of children 1	6.930 (0.020)	-1.550 (-0.990)	0.180 (0.100)	-0.630 (-0.790)	-0.120 (-0.200)
	age and presence of	-0.610	-0.500	0.040	-0.180	-0.190

	children 2	(-0.020)	(-0.880)	(0.090)	(-1.170)	(-1.610)
	age and presence of children 3	-10.000 (-0.010)	-0.230 (-0.750)	0.150 (0.640)	-0.020 (-0.280)	-0.020 (-0.310)
	age and presence of children 6	-1.020 (-0.020)	-0.130 (-0.540)	-0.10 (-0.530)	-0.080 (-1.070)	-0.130 (-2.20) **
	age of household head 1	-0.840 (-0.020)	-0.090 (-0.40)	-0.030 (-0.160)	-0.040 (-0.520)	-0.040 (-0.690)
	age of household head 3	-1.270 (-0.030)	-0.440 (-2.030) *	0.050 (0.210)	-0.210 (-2.470) ***	-0.230 (-3.60) ***
	age of household head 4	-0.060 (-0.010)	-0.220 (-0.280)	-0.110 (-0.070)	-0.120 (-0.180)	-0.170 (-0.310)
	Education level of household head 1	0.010 (0.010)	-0.040 (-0.050)	-0.010 (-0.010)	0.010 (0.020)	-0.040 (-0.070)
	Education level of household head 2	-0.200 (-0.040)	-0.030 (-0.040)	-0.180 (-0.120)	-0.060 (-0.090)	-0.140 (-0.260)
	Education level of household head 3	0.110 (0.030)	-0.330 (-0.350)	0.070 (0.050)	-0.100 (-0.150)	-0.040 (-0.070)
	Education level of household head 4	0.100 (0.030)	-0.070 (-0.180)	0.080 (0.140)	0.060 (0.220)	0.010 (0.030)
	Education level of household head 5	-0.050 (0.010)	-0.580 (0.010)	-0.040 (0.010)	-0.330 (-1.210)	-0.250 (-1.050)
	Annual income 1	0.120 (0.010)	0.520 (0.010)	-1.220 (0.010)	-0.220 (-0.050)	-0.050 (-0.030)
	Annual income 2	0.410 (0.010)	0.350 (0.010)	-0.020 (0.010)	0.170 (0.290)	0.160 (0.280)
	Annual income 3	-0.170 (-0.520)	0.040 (0.400)	0.110 (0.730)	0.080 (1.230)	0.020 (0.340)
	Annual income 4	0.050 (0.170)	0.140 (1.520)	0.010 (0.060)	0.080 (1.350)	0.060 (1.320)
	Annual income 5	0.030 (0.130)	0.040 (0.380)	-0.010 (-0.090)	0.030 (0.460)	0.020 (0.490)
	Origin as rural	0.240 (0.410)	0.090 (0.390)	0.030 (0.130)	0.080 (0.770)	0.070 (0.870)
Demographics in chicken equation	Constant	-0.020 (-0.050)	-0.070 (-0.530)	0.020 (0.180)	-0.020 (-0.280)	-0.030 (-0.550)
	region1	-0.160 (-0.430)	-0.100 (-0.630)	-0.030 (-0.190)	-0.070 (-0.780)	-0.090 (-1.310)
	region2	0.100 (0.370)	-0.150 (-1.770)	-0.140 (-1.360)	-0.140 (-2.70) ***	-0.100 (-2.350) ***
	region3	-0.100 (-0.320)	-0.110 (-0.790)	0.010 (0.030)	-0.050 (-0.690)	-0.070 (-1.130)
	region4	0.020 (0.040)	0.020 (0.140)	0.070 (0.450)	0.030 (0.360)	0.040 (0.670)
	region5	0.230 (0.380)	0.080 (0.390)	0.070 (0.340)	0.070 (0.740)	0.110 (1.400)
	household size1	0.130 (0.270)	0.090 (0.510)	0.080 (0.380)	0.050 (0.630)	0.080 (1.190)
	household size2	-0.030 (-0.070)	-0.060 (-0.370)	0.110 (0.590)	0.010 (0.050)	0.010 (0.170)
	household size3	0.080 (0.180)	-0.120 (-0.850)	0.040 (0.240)	-0.060 (-0.760)	-0.030 (-0.510)
	household size4	-0.030	-0.010	-0.020	-0.030	-0.030

		(-0.110)	(-0.180)	(-0.180)	(-0.560)	(-0.660)
	age and presence of children 1	-3.340 (-0.010)	0.690 (0.60)	-0.270 (-0.210)	-0.290 (-0.560)	-0.280 (-0.780)
	age and presence of children 2	0.080 (0.010)	0.300 (0.560)	0.150 (0.30)	-0.010 (-0.110)	0.010 (0.140)
	age and presence of children 3	0.880 (0.010)	0.110 (0.370)	0.040 (0.140)	-0.020 (-0.490)	-0.020 (-0.580)
	age and presence of children 6	0.480 (0.010)	0.10 (0.390)	-0.080 (-0.530)	0.020 (0.310)	0.040 (0.910)
	age of household head 1	0.690 (0.020)	0.060 (0.290)	0.080 (0.350)	0.010 (0.020)	0.010 (0.310)
	age of household head 3	0.910 (0.020)	0.010 (0.080)	0.160 (0.480)	0.020 (0.310)	0.010 (0.260)
	age of household head 4	0.130 (0.070)	0.050 (0.10)	0.130 (0.120)	0.020 (0.030)	0.100 (0.330)
	Education level of household head 1	0.120 (0.070)	0.070 (0.150)	0.130 (0.120)	0.040 (0.080)	0.110 (0.370)
	Education level of household head 2	0.260 (0.150)	0.020 (0.050)	0.030 (0.030)	-0.020 (-0.050)	0.080 (0.280)
	Education level of household head 3	0.170 (0.070)	-0.020 (-0.040)	0.020 (0.010)	0.040 (0.090)	0.060 (0.20)
	Education level of household head 4	0.060 (0.050)	0.080 (0.350)	0.160 (0.590)	0.040 (0.370)	0.10 (1.070)
	Education level of household head 5	-0.330 (0.010)	-0.010 (0.010)	-0.050 (0.010)	-0.010 (-0.030)	-0.080 (-0.270)
	Annual income 1	-0.190 (0.010)	0.210 (0.010)	0.020 (0.010)	0.030 (0.020)	-0.070 (-0.090)
	Annual income 2	-0.070 (0.010)	0.120 (0.010)	0.060 (0.010)	-0.010 (-0.020)	0.050 (0.070)
	Annual income 3	0.060 (0.260)	0.030 (0.370)	0.010 (0.150)	0.010 (0.220)	0.020 (0.570)
	Annual income 4	0.040 (0.180)	0.010 (0.130)	0.080 (0.910)	0.030 (0.760)	0.030 (0.910)
	Annual income 5	-0.060 (-0.280)	-0.020 (-0.300)	0.080 (0.830)	0.020 (0.510)	0.010 (0.020)
	Origin as rural	-0.210 (-0.590)	-0.080 (-0.640)	-0.040 (-0.270)	-0.060 (-0.910)	-0.070 (-1.180)
Demographics in turkey equation	Constant	-0.150 (-0.560)	-0.030 (-0.340)	-0.010 (-0.120)	-0.010 (-0.240)	-0.040 (-1.050)
	region1	-0.010 (-0.040)	-0.030 (-0.290)	-0.090 (-0.750)	-0.050 (-0.870)	-0.030 (-0.660)
	region2	-0.090 (-0.490)	0.010 (-0.060)	-0.010 (-0.160)	-0.010 (-0.240)	-0.030 (-0.750)
	region3	-0.050 (-0.230)	0.020 (0.200)	-0.150 (-1.450)	-0.050 (-1.040)	-0.050 (-1.230)
	region4	0.080 (0.270)	0.140 (1.530)	-0.090 (-0.820)	0.030 (0.640)	0.040 (0.900)
	region5	0.150 (0.410)	0.050 (0.570)	-0.070 (-0.560)	-0.020 (-0.320)	0.010 (0.320)
	household size1	0.110 (0.350)	0.10 (1.080)	-0.010 (-0.110)	0.050 (0.890)	0.060 (1.270)
	household size2	0.090 (0.290)	0.130 (0.920)	0.010 (0.100)	0.080 (1.110)	0.080 (1.510)
	household size3	0.040 (0.190)	0.170 (1.610)	-0.060 (-0.710)	0.060 (1.50)	0.050 (1.590)

	household size4	-0.150 (-0.670)	-0.070 (-1.270)	-0.020 (-0.260)	-0.050 (-1.590)	-0.070 (-2.990) ***
	age and presence of children 1	2.050 (0.010)	-0.080 (-0.060)	-0.10 (-0.060)	0.370 (0.540)	0.110 (0.220)
	age and presence of children 2	-0.140 (0.010)	0.140 (0.240)	-0.260 (-0.370)	0.010 (-0.020)	-0.030 (-0.280)
	age and presence of children 3	-2.020 (-0.020)	0.160 (0.550)	-0.140 (-0.310)	0.070 (0.980)	0.040 (0.690)
	age and presence of children 6	-0.590 (-0.010)	0.090 (0.390)	0.120 (0.500)	0.010 (0.120)	0.020 (0.400)
	age of household head 1	-1.390 (-0.030)	0.030 (0.170)	-0.190 (-0.600)	-0.030 (-0.570)	-0.090 (-2.150) *
	age of household head 3	-1.480 (-0.030)	0.040 (0.230)	-0.060 (-0.130)	0.060 (0.920)	0.060 (1.190)
	age of household head 4	-0.470 (-0.110)	-0.120 (-0.170)	-0.110 (-0.090)	-0.180 (-0.320)	-0.260 (-0.590)
	Education level of household head 1	-0.450 (-0.110)	-0.070 (-0.10)	-0.170 (-0.130)	-0.170 (-0.310)	-0.250 (-0.570)
	Education level of household head 2	-0.490 (-0.110)	0.010 (0.010)	-0.010 (-0.010)	-0.070 (-0.130)	-0.190 (-0.440)
	Education level of household head 3	-0.530 (-0.140)	0.060 (0.080)	-0.330 (-0.280)	-0.160 (-0.320)	-0.190 (-0.440)
	Education level of household head 4	0.020 (0.010)	-0.040 (-0.10)	0.040 (0.070)	-0.050 (-0.210)	-0.080 (-0.510)
	Education level of household head 5	0.130 (0.010)	-0.010 (0.010)	-0.020 (0.010)	-0.020 (-0.010)	0.050 (0.100)
	Annual income 1	-0.10 (0.010)	-0.560 (0.010)	1.120 (0.010)	0.10 (0.090)	-0.220 (-0.240)
	Annual income 2	-0.290 (0.010)	-0.110 (0.010)	-0.20 (0.010)	-0.150 (-0.400)	-0.240 (-0.760)
	Annual income 3	0.080 (0.280)	0.110 (0.800)	0.20 (1.170)	0.150 (1.710)	0.120 (1.840)
	Annual income 4	-0.260 (-1.290)	-0.010 (-0.070)	0.050 (0.560)	0.010 (0.290)	-0.040 (-1.050)
	Annual income 5	-0.150 (-0.600)	-0.050 (-0.560)	0.070 (0.600)	0.010 (0.010)	-0.020 (-0.500)
	Origin as rural	-0.070 (-0.160)	-0.210 (-1.440)	0.060 (0.360)	-0.080 (-0.990)	-0.090 (-1.290)
Beef, pork, chicken, turkey equations	Beef price*seafood price	0.060 (0.230)	0.010 (0.040)	0.050 (0.410)	0.040 (0.730)	0.030 (0.600)
	Chicken price*seafood price	0.140 (0.400)	-0.140 (-1.270)	0.130 (0.880)	0.010 (0.090)	0.010 (0.260)
	Turkey price*seafood price	0.010 (0.060)	-0.120 (-1.260)	0.070 (0.690)	-0.020 (-0.450)	-0.020 (-0.450)
	Seafood price*seafood price	0.210 (0.580)	0.120 (0.860)	0.150 (0.910)	0.130 (1.810)	0.150 (2.230) **
	Beef price*turkey price	0.010 (0.010)	0.010 (0.080)	-0.040 (-0.300)	-0.020 (-0.290)	-0.010 (-0.240)
	Chicken price*turkey price	0.010 (0.040)	0.010 (-0.020)	0.010 (0.090)	-0.020 (-0.220)	-0.010 (-0.220)
	Turkey price*turkey price	-0.120 (-0.410)	0.090 (0.710)	-0.020 (-0.140)	0.040 (0.470)	0.010 (0.210)

	Beef price*chicken price	0.030 (0.090)	0.050 (0.270)	-0.130 (-0.860)	-0.040 (-0.540)	-0.020 (-0.380)
	Chicken price*chicken price	0.060 (0.130)	-0.210 (-2.080) *	-0.110 (-0.770)	-0.160 (-2.330) **	-0.090 (-1.770)
	Beef price*beef price	0.010 (0.060)	0.020 (0.240)	0.020 (0.180)	0.030 (0.480)	0.020 (0.440)
	Lagged beef disappearance	-0.230 (-3.20) ***	-0.160 (-7.120) ***	-0.30 (-7.560) ***	-0.210 (-12.40) ***	-0.190 (-14.880) ***
	Lagged pork disappearance	-0.270 (-3.180) ***	-0.180 (-8.210) ***	-0.350 (-8.090) ***	-0.240 (-13.950) ***	-0.220 (-16.350) ***
	Lagged chicken disappearance	-0.180 (-2.960) ***	-0.110 (-7.390) ***	-0.190 (-6.570) ***	-0.140 (-11.270) ***	-0.130 (-13.20) ***
	Lagged turkey disappearance	-0.070 (-3.030) ***	-0.070 (-7.220) ***	-0.120 (-6.930) ***	-0.090 (-12.340) ***	-0.080 (-14.680) ***
	Lagged seafood disappearance	-0.490 (-2.880) ***	-0.430 (-6.880) ***	-0.420 (-5.030) ***	-0.40 (-10.130) ***	-0.390 (-12.180) ***

a: Due to the fact that the models based on period 2002-2003,2004-2005 and 2006-2007 have high multi-collinearity among estimated parameters, the parameter significance may not be reliable. Therefore, we use the models based on 2002-2007 and 2004-2007 to evaluate the significance of parameters.

b: ”*,**,***” represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses.

Table C.9 Definitions of variables

Variable	Definitions
Region1	Maritimes
Region2	Quebec
Region3	Ontario
Region4	Man/Sask.
Region5	Alberta
Household size1	Households with single Member
Household size2	Households with two Members
Household size3	Households with three Members
Household size4	Households with four Members
Age and presence of children 1	Households that have children with age under 6 only, or with ages under 6 and age 6 to 12, or with ages under 6, 6 to 12 and13 to 17.
Age and presence of children 2	Households that have children with age 6 to 12 only
Age and presence of children 3	Households that have children with age 13 to 17 only
Age and presence of children 6	Households that have children with ages 6 to 12 and age 13 to 17
Age of household head 1	Household heads with ages 18 to 44
Age of household head 3	Household heads with ages 45 to 54

Age of household head 4	Household heads with ages 55 to 64
Education level of household head 1	Household heads with education levels " Not high school graduates"
Education level of household head 2	Household heads with education levels " High school graduates"
Education level of household head 3	Household heads with education levels " In some college and technical school"
Education level of household head 4	Household heads with education levels " College and technical school graduates"
Education level of household head 5	Household heads with education levels " In some university"
Annual income 1	Households annual income <$ 20,000
Annual income 2	Households annual income $ 20,000-$29,999
Annual income 3	Households annual income $30,000-$39,999
Annual income 4	Households annual income $40,000-$49,999
Annual income 5	Households annual income $50,000-$69,999

Table C.10 The Values of Endogenous Variables in the North American Beef Sector Model in 2002 and 2008

Variables \ Year	2002	2008	Changes
Beef retail prices in Canada ($/kg)	9.193	9.003	-0.190
Beef demand in Canada (1000 tonnes)	949.287	1063.900	114.613
Beef retail prices in the U.S. ($/kg)	6.729	9.535	2.806
Beef demand in the U.S. (1000 tonnes)	12644.795	12384.043	-260.752
Net exports of beef from Canada to the U.S. (1000 tonnes)	213.966	208.518	-5.448
Net exports of beef from Canada to the rest of the world (1000 tonnes)	120.154	110.015	-10.139
Net exports of beef from the U.S. to the rest of the world (1000 tonnes)	-135.252	-90.334	44.919
Steers and heifers slaughtered in Western Canada (1000 head)	2228.940	1970.035	-258.905
Steers and heifers slaughtered in Eastern Canada (1000 head)	679.290	667.426	-11.864
Steers and heifers slaughtered in the U.S. (1000 head)	29367.000	27253.492	-2113.508
Cows and bulls slaughtered in Western Canada (1000 head)	363.291	612.870	249.579
Cows and bulls slaughtered in Eastern Canada (1000 head)	186.996	217.928	30.932
Cows and bulls slaughtered in the U.S.	6370.000	6808.961	438.961

(1000 head)			
Net exports of slaughter steers and heifers from Western Canada to the U.S. (1000 head)	569.182	652.531	83.349
Net exports of slaughter steers and heifers from Eastern Canada to the U.S. (1000 head)	168.267	243.112	74.845
Net exports of slaughter cows and bulls from Western Canada to the U.S. (1000 head)	250.412	175.267	-75.145
Net exports of slaughter cows and bulls from Eastern Canada to the U.S. (1000 head)	121.883	10.113	-111.770
Prices of slaughter steers and heifers in the U.S. ($/lb)	0.670	0.930	0.260
Prices of slaughter cows and bulls in the U.S. ($/lb)	0.392	0.481	0.089
Prices of slaughter steers and heifers in Western Canada ($/lb)	0.983	0.903	-0.080
Prices of slaughter steers and heifers in Eastern Canada ($/lb)	1.024	0.906	-0.118
Prices of feeder cattle in Western Canada ($/lb)	1.320	1.046	-0.274
Prices of feeder cattle in Eastern Canada ($/lb)	1.264	1.060	-0.204
Prices of cows and bulls in Western Canada ($/lb)	0.573	0.430	-0.144
Prices of cows and bulls in Eastern Canada ($/lb)	0.633	0.419	-0.214
Revenue from cows and bulls slaughtered in Western Canada (million $)	1261.755	2084.561	822.806
Revenue from steers and heifers slaughtered in Western Canada (million $)	7741.388	6700.700	-1040.688
Revenue from cows and bulls slaughtered in Eastern Canada (million $)	649.461	741.241	91.780
Revenue from steers and heifers slaughtered in Eastern Canada (million $)	2359.259	2270.123	-89.136
Revenue from cows and bulls slaughtered in the U.S. (million $)	16193.816	23051.475	6857.659
Revenue from steers and heifers slaughtered in the U.S. (million $)	74656.795	92265.648	17608.853
Revenue from beef sales in Canada (million $)	7241.317	9577.973	2336.656
Revenue from beef sales in the U.S. (million $)	85084.037	118080.609	32996.572

Appendix D

Doublelog-Translog Demand System

A doublelog function in the first stage of demand system can be written as (Goddard et al., 2004):

$$LnE_m = Ln(\overline{P}_m\overline{Q}_m) = a_0 + a_1 Ln\overline{P}_m + a_2 LnPDI \qquad \text{(D.1)}$$

where $\overline{P}_m$ and $\overline{Q}_m$ are the aggregate price and quantitiy in group m and $\overline{P}_m\overline{Q}_m$ is the household expenditure for group m. PDI is per capita disposable income.α's are parameters to be estimated.

The functional form in the second stage is derived from a TransLog indirect utility function, which is the second order Taylor series expansion of an arbitrary indirect utility function. The Translog indirect utility function[63] is specified as:

$$Log(v_m) = Log(a_0) + \sum_i a_i Log(\frac{P_i}{E_m}) + \sum_i \sum_j \tau_{ij} Log(\frac{P_i}{E_m}) Log(\frac{P_j}{E_m}) \qquad \text{(D.2)}$$

Share equations based on normalized prices

$$w_i = -\frac{a_i + \sum_j \tau_{ij} Log(\frac{P_j}{E_m})}{\sum_j a_j + \sum_i \sum_j \tau_{ij} Log(\frac{P_j}{E_m})} \qquad \text{(D.3)}$$

where P_i and W_i is the price and expenditure share of i^{th} good at group m. Denoting $N_i = a_i + \sum_j \tau_{ij} Log(\frac{P_j}{E_m})$, $D = \sum_j a_j + \sum_i \sum_j \tau_{ij} Log(\frac{P_j}{E_m})$,the hypotheses implied by a well-defined utility function include:

Symmetry: $\tau_{ij} = \tau_{ji}$

Monotonicity: $\frac{\partial v_m}{\partial(\frac{P_i}{E_m})} = \frac{v_m}{\frac{P_i}{E_m}}[a_i + \sum_j \tau_{ij} Log(\frac{P_i}{E_m})] < 0 \rightarrow N_i < 0$

Adding-up: $\sum_j w_j = 1$

Convexity: the bordered Hessian H of the indirect utility function is convex in its elements.

[63] Zero homogeneity has been imposed here.

$$H = \begin{pmatrix} 0 & v_1 & \cdots & v_n \\ v_1 & v_{11} & \cdots & v_{1n} \\ \vdots & \vdots & v_{ij} & \vdots \\ v_n & v_{1n} & \cdots & v_{nn} \end{pmatrix} \qquad \text{i,j=1,…,n}$$

$$v_{ii} = \frac{\partial^2 v}{\partial^2 (\frac{P_i}{E_m})} = \frac{v}{(\frac{P_i}{E_m})^2}[\tau_{ii} - N_i + N_i^2]$$

$$v_{ij} = \frac{\partial^2 v}{\partial (\frac{P_i}{E_m}) \partial (\frac{P_j}{E_m})} = \frac{v}{(\frac{P_i}{E_m})(\frac{P_j}{E_m})}[\tau_{ij} + N_i N_j]$$

Multiple stage demand system requires the homothetic separability, which can be expressed as: $\sum_j \tau_{ij} = 0$

The conditional and unconditional elasticities are calculated through the following table:

Elasticity type	Uncompensated		Compensated
	Own-price and cross price elasticities (ε_{ij}^m)	Expenditure Elasticities (η_i)	Own-price and Cross price Elasticities ($\varepsilon_{ij}^h = \varepsilon_{ij}^m + \eta_i s_j$)
First stage elasticities	$a_1 * \delta_{ij}$	a_2	$(a_1 + a_2 * \frac{E_m}{PDI}) * \delta_{ij}$
Second stage (conditional) elasticities	$-\delta_{ij} + \frac{1}{D} * \frac{\tau_{ij}}{w_i}$	1	$-\delta_{ij} + \frac{1}{D} * \frac{\tau_{ij}}{w_i} + w_j$
Elasticities across two stages	$-\delta_{ij} + \frac{1}{D} * \frac{\tau_{ij}}{w_i} + w_j * (1 + a_1)$	a_2	$-\delta_{ij} + \frac{1}{D} * \frac{\tau_{ij}}{w_i} + w_j * (1 + a_1)$ $+ a_2 w_j \frac{E_m}{PDI}$

When incorporating risk into demand model, the empirical form of doublelog-TransLog Demand System can be modified as:

$$LnE_{m,t} = Ln(\overline{P}_{m,t}\overline{Q}_{m,t}) = a_0 + a_1 Ln\overline{P}_{m,t} + a_2 LnPDI_t + a_3 * \beta_t \tag{D.4}$$

$$w_{i,t} = -\frac{a_i + \sum_j \tau_{ij} Log(\frac{P_{j,t}}{E_{m,t}}) + v_i * \beta_t}{\sum_j a_j + \sum_i \sum_j \tau_{ij} Log(\frac{P_{j,t}}{E_{m,t}}) + \sum_i v_i * \beta_t} \tag{D.5}$$

where β_t represents the risk perception parameter which is evolving over time.

Appendix E

Slaughter cow/bull demand estimation

The cow/bull slaughter demand equations for Western Canada and Eastern Canada are estimated by the following equations.

Slaughter cow/bull demand in Western Canada:

$$D_t^{cb,w} = \gamma_0 + \gamma_1 * \frac{P_t^{cb,w}}{bank_t} + \gamma_2 * \frac{P_t^{r,CA}}{bank_t} + \gamma_3 * D_{t-1}^{cb,w} + \gamma_4 * Q_1 + \gamma_5 * Q_2 + \gamma_6 * Q_3$$

$$+\gamma_7 * liftussc + \gamma_8 * liftussc2 + \gamma_9 * ABSL + \gamma_{10} * BCSL$$

Slaughter cow/bull demand in Eastern Canada:

$$D_t^{cb,e} = \varphi_0 + \varphi_1 * \frac{P_t^{cb,e}}{bank_t} + \varphi_2 * \frac{P_t^{r,CA}}{bank_t} + \varphi_3 * D_{t-1}^{cb,e} + \varphi_4 * Q_1 + \varphi_5 * Q_2 + \varphi_6 * Q_3 +$$

$$\varphi_7 * liftussc + \varphi_8 * liftussc2$$

where :

$bank_t$	Interest rates in Canada
$D_t^{cb,w}, D_t^{cb,e}$	Cows and bulls slaughtered in Western or Eastern Canada
$P_t^{r,CA}, P_t^{r,US}$	Beef retail prices in Canada or the U.S.
$P_t^{cb,w}, P_t^{cb,e}$	Prices of cows in Western or Eastern Canada
Q_1, Q_2, Q_3	Quarterly dummies for the first, second and third quarter.
$liftussc$	Dummy for the third quarter, 2005, when the U.S. border is open to Canadian cattle and bison less than 30 months of age
$liftussc2$	Dummy for U.S. border was open to all age Canadian cattle in November, 2007
DBSE	Dummy for BSE outbreak in the second quarter, 2003
ABSL	Significant changes of slaughter cow demand in Alberta. ABSL=1 if cow slaughter is less than 20% of annual monthly average in 12 months before BSE in Alberta; 0 otherwise
BCSL	Significant changes of slaughter cow demand in B.C., Manitoba/Saskatchewan. BCSL=1 if cow slaughter is less than 20% of annual monthly average in 12 months before BSE in B.C., Manitoba/Saskatchewan; 0 otherwise

The equations are estimated over the period the first quarter,1978-the fourth quarter, 2008. The dummies for significant changes of slaughter cows in Alberta and B.C. are incorporated to track structural changes in the slaughter cow demand in Western Canada. The dummies for border re-opening from other countries are also incorporated initially but only the dummies for the border re-opening from the U.S. are statistically significant in Western Canada. Therefore, the dummies of border re-opening from other countries except the U.S. are removed by likelihood ratio tests to improve the model fit. The estimation results of the final model are shown as follows:

Slaughter cow/bull demand in Western Canada:

$$D_t^{cb,w} = 53.163 - 0.457 * \frac{P_t^{cb,w}}{bank_t} + 4.301 * \frac{P_t^{r,CA}}{bank_t} + 0.592 * D_{t-1}^{cb,w} - 22.759 * Q_1$$

(7.653) (-1.455) (1.624) (8.446) (-6.261)

$$-39.365 * Q_2 - 33.184 * Q_3 + 16.652 * liftussc + 18.050 * liftussc2$$

(-11.212) (-11.331) (3.696) (2.513)

$$-14.950 * ABSL - 16.513 * BCSL$$

(-1.972) (-2.671) (t-stat) $R^2 = 0.829$

Slaughter cow/bull demand in Eastern Canada:

$$D_t^{cb,e} = 28.432 - 0.455 * \frac{P_t^{cb,e}}{bank_t} + 0.546 * \frac{P_t^{r,CA}}{bank_t} + 0.797 * D_{t-1}^{cb,e} - 12.789 * Q_1$$

(6.943) (-2.587) (.439) (17.165) (-6.770)

$$-16.083 * Q_2 - 17.494 * Q_3$$

(-8.682) (-9.859) (t-stat) $R^2 = 0.810$

Elasticities		Western Canada	Eastern Canada
Short run	Elasticities of slaughter cow/bull demand with respect to beef retail price	0.561 (1.624)	0.083 (0.439)
	Elasticities of slaughter cow/bull demand with respect to cow/bull price	-0.280 (-1.455)	-0.340 (-2.587) ***
Long run	Elasticities of slaughter cow/bull demand with respect to beef retail price	1.370 (1.713) #	0.410 (0.437)
	Elasticities of slaughter cow/bull demand with respect to cow/bull price	-0.680 (-1.527)	-1.680 (-2.874) ***

”*,**,***” represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses；# represents 90% level of significance.

Slaughter steer/heifer demand estimation

The slaughter steer/heifer slaughter demand equations for Western Canada and Eastern Canada are estimated by the following equations.

Slaughter steer/heifer demand in Western Canada:

$$D_t^{sh,w} = \rho_0 + \rho_1 * \frac{P_t^{sh,w}}{bank_t} + \rho_2 * \frac{P_t^{r,CA}}{bank_t} + \rho_3 * D_{t-1}^{sh,w} + \rho_4 * Q_1 + \rho_5 * Q_2 + \rho_6 * Q_3$$

Slaughter steer/heifer demand in Eastern Canada:

$$D_t^{sh,e} = \emptyset_0 + \emptyset_1 * \frac{P_t^{sh,e}}{bank_t} + \emptyset_2 * \frac{P_t^{r,CA}}{bank_t} + \emptyset_3 * D_{t-1}^{sh,e} + \emptyset_4 * Q_1 + \emptyset_5 * Q_2 + \emptyset_6 * Q_3$$

where :

$D_t^{sh,w}, D_t^{sh,e}$	Steers and heifers slaughtered in Western or Eastern Canada
$P_t^{sh,w}, P_t^{sh,e}$	Prices of steers and heifers slaughtered in Western or Eastern Canada
ρ and $\emptyset$	Parameters to be estimated

The equations are estimated over the period the first quarter,1990-the fourth quarter, 2008. The dummies for border re-opening from other countries and significant changes in slaughter demand are also incorporated initially but none of them are statistically significant. Therefore, these dummies are removed by likelihood ratio tests to improve the model fit. The estimation results of the final model are shown as follows:

Slaughter steer/heifer demand in Western Canada:

$$D_t^{sh,w} = 4.412 - 4.084 * \frac{P_t^{sh,w}}{bank_t} + 48.095 * \frac{P_t^{r,CA}}{bank_t} + 0.873 * D_{t-1}^{sh,w} + 48.089 * Q_1$$

(0.172) (-2.299) (2.806) (14.264) (3.753)

$$+100.634 * Q_2 + 28.305 * Q_3$$

(8.083) (2.259) (t-stat) $R^2 = 0.879$

Slaughter steer/heifer demand in Eastern Canada:

$$D_t^{sh,e} = 66.195 - 1.101 * \frac{P_t^{sh,e}}{bank_t} + 14.557 * \frac{P_t^{r,CA}}{bank_t} + .555 * D_{t-1}^{sh,e} - 1.199 * Q_1$$

(4.806) (-2.888) (3.800) (6.559) (-.404)

$$+11.092 * Q_2 + 0.458 * Q_3$$

(3.759) (0.157) (t-stat) $R^2 = 0.632$

Elasticities		Western Canada	Eastern Canada
Short run	Elasticities of slaughter steer/heifer demand with respect to beef retail price	0.138 (1.591)	0.414 (2.737) ***
	Elasticities of slaughter steer/heifer demand with respect to steer/heifer price	-0.096 (-1.699) #	-0.265 (-2.382) **
Long run	Elasticities of slaughter steer/heifer demand with respect to beef retail price	1.085 (2.806) ***	0.930 (3.800) ***
	Elasticities of slaughter steer/heifer demand with respect to steer/heifer price	-0.751 (-2.299) **	-0.595 (-2.888) ***

"*,**,***" represent 95%, 97.5% and 99% level of significance respectively. T-statistics are in parentheses；# represents 90% level of significance.

Appendix F
Questions in the consumer survey

General Trust

Generally speaking, would you say that most people can be trusted?

People can be trusted	Can't be too careful in dealing with people	Don't know
❒	❒	❒

How much do you trust each of the following groups of people?

	Cannot be trusted at all	Somewhat untrustworthy	Slightly untrustworthy	Somewhat trustworthy	Can be trusted a lot	Don't know
	1	2	3	4	5	6
People in your family	❒	❒	❒	❒	❒	❒
People in your neighbourhood	❒	❒	❒	❒	❒	❒
People you work or go to school with	❒	❒	❒	❒	❒	❒
Doctors or nurses	❒	❒	❒	❒	❒	❒
Scientists	❒	❒	❒	❒	❒	❒
Consumer Organizations	❒	❒	❒	❒	❒	❒
Environmental organizations	❒	❒	❒	❒	❒	❒
Media sources	❒	❒	❒	❒	❒	❒
Strangers	❒	❒	❒	❒	❒	❒

How often do you lend money to your friends?

Never	Infrequently	Moderately often	Frequently	Regularly
1	2	3	4	5
❒	❒	❒	❒	❒

Respondent general traits

We would like to know whether you, **in general**, worry a lot in daily life. Please indicate to what extent you find the following statements characteristic of yourself. Give your answer on a scale from 1 ("not at all typical") to 5 ("very typical").

	not at all typical 1	2	somewhat typical 3	4	very typical 5
Many situations make me worry	❒	❒	❒	❒	❒
I know I shouldn't worry about things, but I just cannot help it	❒	❒	❒	❒	❒
I notice that I have been worrying about things	❒	❒	❒	❒	❒

Food Attitudes

	strongly disagree 1	disagree 2	neither agree, nor disagree 3	agree 4	strongly agree 5
I am optimistic about the safety of food products	❒	❒	❒	❒	❒
I am confident that food products are safe	❒	❒	❒	❒	❒
I am satisfied with the safety of food products	❒	❒	❒	❒	❒
Generally, food products are safe	❒	❒	❒	❒	❒

Food Attitudes

	strongly disagree 1	disagree 2	neither agree, nor disagree 3	agree 4	strongly agree 5
I worry about the safety of food	❒	❒	❒	❒	❒
I feel uncomfortable regarding the safety of food	❒	❒	❒	❒	❒
As a result of the occurrence of food safety incidents I am suspicious about certain food products	❒	❒	❒	❒	❒

Perceived safety of meat

Please indicate how much confidence you, generally, have in the safety of the following product groups. Give your answer on a scale from 1 ("no confidence at all") to 5 ("complete confidence").

	no confidence at all 1	2	3	4	complete confidence 5
Beef	❒	❒	❒	❒	❒
Chicken / poultry	❒	❒	❒	❒	❒

Attitudes towards eating beef

What do you think about eating beef?

When eating beef, I am exposed to …						
	1	2	3	4	5	
very little risk	❐	❐	❐	❐	❐	a great deal of risk
I accept the risks of eating beef						
strongly disagree	❐	❐	❐	❐	❐	strongly agree
I think eating beef is risky						
strongly disagree	❐	❐	❐	❐	❐	strongly agree
For me, eating beef is …						
not risky	❐	❐	❐	❐	❐	risky
For me, eating beef is worth the risk						
strongly disagree	❐	❐	❐	❐	❐	strongly agree
I am … the risk of eating beef						
not willing to accept	❐	❐	❐	❐	❐	willing to accept

Trust in food industry

	strongly disagree	**disagree**	**neither agree, nor disagree**	**agree**	**strongly agree**
	1	**2**	**3**	**4**	**5**
Manufacturers have the competence to control the safety of food	❐	❐	❐	❐	❐
Manufacturers have sufficient knowledge to guarantee the safety of food products	❐	❐	❐	❐	❐
Manufacturers are honest about the safety of food	❐	❐	❐	❐	❐
Manufacturers are sufficiently open about the safety of food	❐	❐	❐	❐	❐
Manufacturers take good care of the safety of our food	❐	❐	❐	❐	❐
Manufacturers give special attention to the safety of food	❐	❐	❐	❐	❐

	strongly disagree	disagree	neither agree, nor disagree	agree	strongly agree
	1	2	3	4	5
Retailers have the competence to control the safety of food	❒	❒	❒	❒	❒
Retailers have sufficient knowledge to guarantee the safety of food products	❒	❒	❒	❒	❒
Retailers are honest about the safety of food	❒	❒	❒	❒	❒
Retailers are sufficiently open about the safety of food	❒	❒	❒	❒	❒
Retailers take good care of the safety of our food	❒	❒	❒	❒	❒
Retailers give special attention to the safety of food	❒	❒	❒	❒	❒

	strongly disagree	disagree	neither agree, nor disagree	agree	strongly agree
	1	2	3	4	5
The government has the competence to control the safety of food	❒	❒	❒	❒	❒
The government has sufficient knowledge to guarantee the safety of food products	❒	❒	❒	❒	❒
The government has honest about the safety of food	❒	❒	❒	❒	❒
The government has sufficiently open about the safety of food	❒	❒	❒	❒	❒
The government takes good care of the safety of our food	❒	❒	❒	❒	❒
The government gives special attention to the safety of food	❒	❒	❒	❒	❒

	strongly disagree	disagree	neither agree, nor disagree	agree	strongly agree
	1	2	3	4	5
Farmers have the competence to control the safety of food	❒	❒	❒	❒	❒
Farmers have sufficient knowledge to guarantee the safety of food products	❒	❒	❒	❒	❒
Farmers are honest about the safety of food	❒	❒	❒	❒	❒
Farmers are sufficiently open about the safety of food	❒	❒	❒	❒	❒
Farmers take good care of the safety of our food	❒	❒	❒	❒	❒
Farmers give special attention to the safety of food	❒	❒	❒	❒	❒

Animal production related concerns

To what extent are you concerned about the following issues?

	not at all concerned	Minor concerns	Some concerns	Major Concerns	very concerned
	1	2	3	4	5
The feed given to livestock	❐	❐	❐	❐	❐
Conditions in which food animals are raised	❐	❐	❐	❐	❐
Genetically modified animal feeds	❐	❐	❐	❐	❐
Animal diseases	❐	❐	❐	❐	❐
BSE and Creutzfeldt Jakob Disease (vCJD)	❐	❐	❐	❐	❐
The origin of products/ animals	❐	❐	❐	❐	❐
Antibiotics in meat	❐	❐	❐	❐	❐

Recall of media coverage on BSE

To what extent have you seen, heard, or read any news messages in the media about BSE(mad cow disease) over the past five years?

Very few messages	Few messages	Some messages	Frequent messages	Many messages
1	2	3	4	5
❐	❐	❐	❐	❐

If a Canadian cow is found with BSE (mad cow disease) the risk to my family is:

Very low	Low	Neither Low or high	High	Very high
1	2	3	4	5
❐	❐	❐	❐	❐

If you have any awareness of a BSE incident in Canada over the past five years, where did you get your information from?

Friends and family	Newspapers magazines	Radio and TV	Internet	Other	Don’t know
1	2	3	4	5	6
❐	❐	❐	❐	❐	❐

If you have any awareness of a BSE incident in Canada over the past five years, has this had any impact on your confidence in the safety of beef products?

A very small impact	Some impact	Moderate impact	Large impact	A very large impact	Don’t know
1	2	3	4	5	6
❐	❐	❐	❐	❐	❐