Does Canadian beef demand respond to food safety recalls and food quality improvements? *

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Executive Summary

A number of food safety events and recalls have raised consumer awareness of risks associated with food borne pathogens. While consumer confidence in the food system as a whole has not waned in the long run (AAFC 2010), short and medium run aberrations for food products affected by such recalls are not uncommon. The impact of food safety based recalls of meats has been shown to affect demand for those meats (e.g., Verbeke and Ward 2001; Marsh et al. 2004; Piggott and March 2004). However, evidence of the impact of such recalls in Canada is scant. At the same time, little is understood regarding the impact of U.S. food safety based recalls of beef on Canadian beef demand. And while perceptions of food safety are often thought to be an important driver of consumer demand for food products, so too is food quality. In this respect, it is unclear whether broader improvements in beef quality in Canada have increased beef demand in Canada.

The purpose of this research is to answer the following questions:

1. Do food safety related recalls of beef and non-meat food products (arising from possible *E. coli* contamination) in Canada affect beef demand in Canada?

2. Do food safety related recalls of beef and non-meat food products (arising from possible *E. coli* contamination) in the U.S. affect beef demand in Canada?

3. Does enhanced beef quality affect beef demand in Canada?

To answer these questions, a Linear Approximate, Almost Ideal Demand System was estimated using quarterly meat demand data for Canada from 1998 to 2010. In addition to relevant economic variables, the model includes counts of beef, pork and chicken recalls in Canada and the U.S., as well as the count of non-meat recalls in Canada and the U.S. due to possible *E. coli* contamination. Results related to these food safety counts are used to provide answers regarding the first two research questions. The proportion of beef graded

'Prime' or 'AAA' (relative to all beef that is graded 'A' or higher) is used as a measure of beef quality. Results related to the proportion of at least 'AAA' grade beef will provide answers related to the third research question.

Improvements in beef quality had an inverse relation with beef demand in Canada; a one percent increase in beef quality would lead to a 0.2 percent reduction in beef demand in Canada. While seemingly counterintuitive, this relationship could be explained by quantity-quality trade-offs. In particular, when buying a better quality cut of beef, consumers could be buying less quantity, a reflection of economizing on the part of consumers. Results point to structural change in the relationship between beef demand in Canada and the count of beef, pork and chicken recalls. Prior to mid-2008, the relationship between beef demand and beef recalls was positive. After mid-2008, this relationship became negative and suggested that a one-percent increase in beef recalls would lead to a 0.037 percent decrease in beef demand. There was no statistically measurable relationship between beef demand in Canada and the count of non-meat, *E. coli* based recalls in Canada. As well, U.S. recalls of beef did not have a statistically measurable relationship with Canadian beef demand. However, a one-percent increase in U.S. *E. coli* based recalls of non-meat foods lead to a 0.055 percent reduction in Canadian beef demand.

To understand better the impact of a Canadian recall of beef, the beef equation from the model was simulated over the period 1998:Q3 to 2010:Q3 assuming there was one additional recall in each quarter. The simulation was structured in this manner to explore how one additional recall would affect demand at different points in time. On average over this time period, one additional beef recall in Canada lead to a 2.26 million kilogram reduction in beef demand. In value terms, this is equivalent to about $26 million at the retail level, which is equivalent to about one-percent of consumer beef expenditure.

Introduction

A number of high profile food safety events and recalls have raised consumer awareness of risks associated with food borne pathogens. While consumer confidence in the food system as a whole has not waned in the long run (AAFC 2010), short and medium run aberrations for food products affected by such recalls are not uncommon. Indeed, a number of studies have attempted to measure the impact of food safety related recalls of meat. While most of these studies have been undertaken for the U.S. (e.g., Marsh et al. 2004; Piggott and March 2004) or Europe (e.g., Verbeke and Ward 2001), little evidence exists regarding the impact of such recalls on demand for meats in Canada.

Beef is no exception, where a recent recall of some beef products from a cattle processing facility in Canada, due to *E. coli* contamination, had an unknown impact on consumer demand. One might expect that recalls such as this have a negative effect on consumer demand for beef in Canada. However, lack of empirical evidence concerning the size of the retail response to a recall limits our ability measure the subsequent impact, if any, on packer demand for fed-cattle. This, in turn, prevents quantification of the impact of such a recall on the economic well-being of cattle producers.

But note that recalls announced in Canada may not be the only source of demand fluctuation. Food safety related recalls in the U.S. may also affect consumer demand for beef in Canada. To the extent that such recalls appear in Canadian media sources, their impact on demand for beef in Canada is unknown. It is also not clear whether food safety related recalls of non-meat foods affects demand for beef in Canada. Specifically, it is unclear whether recalls of non-meat foods due to possible *E. coli* contamination have spillover effects on the beef sector.

While perceptions of food safety are often thought to be an important driver of consumer demand for food products, so too is food quality more generally (Grunert 2005). A number of studies have explored consumer preferences related to quality improvement. For instance, others have examined consumer preferences and willingness-to-pay (WTP) related to feed regimes (e.g., Umberger et al. 2002; Sitz et al. 2005; Cox et al. 2006), tenderness (e.g., Lusk et al. 2001) and visual appearance (e.g., Killinger et al. 2004) of beef products (typically muscle cuts). However, many of these studies focus on assessing consumer preferences for a particular product attribute, and at a micro-level that does not enable characterization of how broader improvements in product quality affects market demand. Indeed, it is unclear whether broader improvements in beef quality in Canada have increased beef demand in Canada. One might expect that improvements in beef quality enhance consumer satisfaction and lead to increased beef demand in Canada (or at least prevent a decline in beef demand in Canada).

The purpose of this research is to extend an existing model of meat demand in Canada to account for the potential impact of food safety recalls and improvements in the quality of Canadian beef. The research will answer the following questions:

1. Do food safety related recalls of beef and non-meat food products (arising from possible *E. coli* contamination) in Canada affect beef demand in Canada?

2. Do food safety related recalls of beef and non-meat food products (arising from possible *E. coli* contamination) in the U.S. affect beef demand in Canada?

3. Does enhanced beef quality affect beef demand in Canada?

The next section of the paper reviews the relevant literature, with a focus on studies that have explored the role of food scares, food safety based recalls and specific food safety events on firms, consumers and markets, as well as the role of quality in shaping demand. Discussion then shifts to methods and data. Results follow, with a focus on understanding whether an additional recall impacts demand for beef, and whether enhanced beef quality impacts demand. Conclusions and sectoral implications are then discussed.

Previous research

Food safety issues

Numerous studies have noted or documented the rise in food safety related recalls for a variety of food products (e.g. Teratanavat and Hooker 2004; Warriner and Manvar 2009; Bánáti 2011; Potter et al. 2012; Yang et al. 2013). The impact of such recalls on performance of firms affected (or associated) by a recall has been explored using, for example, event study analysis (McKenzie and Thomsen 2001; Salin and Hooker 2001; Henson and Mazzocchi 2002; Jin and Kim 2008; Smart 2010). The impact of such recalls on market outcomes (e.g. prices or marketing margins) has also been explored (e.g. Nardella 2006; Marsh et al. 2008; Park et al. 2008; Schlenker and Villas-Boas 2009; Hassouneh et al 2010; Capps et al. 2013). Generally speaking, these studies conclude that while food safety based recalls have an adverse effect on firm performance or market outcomes (as the case may be), such effects are not permanent and that the size and duration of effect can vary considerably.

Recognize that the firm and market level impacts of such recalls and scares originates with the behaviour of consumers during and after a food safety event. In this respect, focusing attention on the reaction of consumers to food safety recalls becomes very important (Pennings et al. 2002; Wansink 2004; Schroeder et al. 2007; Bánáti 2011). A number of studies have focused on consumer reaction to specific food safety recalls or crises, including the impact of BSE in various countries (Burton and Young 1996; Jin and Koo 2003; Peterson and Chen 2005; Ishida et al. 2010; Bánáti 2011; Ding et al. 2011; Yang and Goddard 2011), avian influenza (Ishida 2010; Bánáti 2011) and other biological (Warriner and Namvar 2009; Arnade 2010; Bánáti 2011; Yang et al. 2013) and non-biological (Bánáti 2011) based food recalls.

More broadly speaking, some studies have investigated the impact of food recalls (or other food safety related information) on demand for a variety of food groups. Recent literature has explored the impact of media indices (i.e. some count of media segments or articles related to a particular food safety issue), or counts of food recalls on demand for beef, pork and poultry products (e.g. Verbeke and Ward 2001; Piggott and March 2004; Marsh et al. 2004; Tonsor et al. 2010; Mo 2013). While the impact of such effects appears mixed, it is generally the case that demand is adversely affected by measures that capture food safety recalls or media coverage of said events. Moreover, results suggest that impacts can last over several periods of time, but with no clear pattern emerging regarding the duration of lagged effects.

In terms of modelling strategy, some have taken a structural approach to capture the impact of food safety recalls. Ishida et al. (2010), using a gradual switching model approach[1] found that demand for beef in Japan experienced permanent structural change during the Japanese BSE crisis in the early 2000s, but that the bird flu crisis had no lasting effect. In contrast, Ding et al. (2011) showed that Canadian beef demand experienced temporary change immediately after BSE was discovered in cattle in Canada.

While the structural approach outlined above is useful, it only lends itself to ex post analysis; such a modelling strategy does not enable one to predict the effect of a future recall on meat demand, or estimate how elastic demand is with respect to a recall. To this end, and building on a literature exploring the impact of health information on demand for various foods (e.g. Brown and Schrader 1990; Kinnucan et al. 1997), some have developed count based measures related to food safety recalls or food crises, and included these counts in analysis of demand for meats. What exactly is counted has varied.

Some studies have elected to develop counts of media coverage (typically newspaper articles) related to particular food safety based recalls (e.g. Burton and Young 1996; Verbeke and Ward 2001; Piggott and Marsh 2004; Marsh et al. 2004; Yang and Goddard 2011; Mo

[1]This approach assumes that the intercept in an Almost Ideal Demand Systems (AIDS) changed during the BSE and bird flu crises in Japan, but allows the change to follow paths that reflect either a temporary change or permanent change

2013). Several issues are worth noting here. Given the nature of print media (i.e. syndication), it is possible that such counts will double count the same newspaper article. Moreover, media articles might reflect a particular slant of the publication in which it appears; some articles on the same event might be neutral, reporting facts, while others might reflect a particular slant that interjects subjective editorial opinion. In such cases, a count of articles will not reflect qualitative differences in them[2]. Lastly, in an age where non-print media is becoming ever pervasive, counts of newspaper articles, even if based on newspapers with electronic formats, might yield a lower bound of an estimate of the actual number of articles. In this case, an under-estimate of the media counts means any measured relationship between demand and the count could be over-stated.

Recognizing these weaknesses, some have resorted to using the counts of recalls issued by agencies with responsibility regarding food safety and food safety recalls (e.g. Marsh et al. 2004; Tonsor et al 2010; Mo 2013). Indeed, in a head-to-head comparison, Marsh et al. (2004) found that including a count of FSIS based recalls in a meat demand systems provided a better fitting model than one estimated with a media based count index. Given that government agency based food recalls are often the source of media coverage of a recall, it seems logical to use a count of recall announcements as the relevant index. It is recognized that some might argue that a count of recall announcements will under-estimate the flow of information to consumers, thus leading to an over-estimate of their effect. Recognize, however, that in estimating the effect of a count of recall notifications on demand, one implicitly accounts for the role of the media - they are, after all, often the source by which such recalls can be diffused. The premise here is that recall notifications lead to media coverage (in addition to any communication efforts by the recalling agency), and the media coverage then leads to consumer reaction (if any). In this sense the estimated response

[2]Admittedly, it is possible to weight articles to account for such slant, but the rules of thumb used to do so are just that, rules of thumb and not guided by an underlying theory or empirical evidence

reflects not just the impact of a recall notification on demand, but also the effectiveness of those who communicate this information and the receptivity of consumers to the recall.

Following Piggott and Marsh (2004), Marsh et al. (2004) and others, this study captures food safety by including a count of the number of food safety related recalls for beef. To explore whether there are differential effects of Canadian versus U.S. recalls on Canadian beef demand, and potential cross-species effects, the model will be estimated including the count of recalls of beef, pork and chicken in both countries, but as separate variables (e.g. recalls of beef in Canada will be differentiated from recalls of beef in the U.S., etc). This will enable determination of spillover effects of recalls of meat from one species onto another, and whether there are international spillover effects on Canadian beef demand from food safety based meat recalls in the U.S. To explore whether *E. coli* based recalls of non-meat foods affect beef demand (and meat demands in general), the count of such recalls in Canada and the U.S. will also be included as separate variables.

Role of meat quality and grades

Previous studies have assessed consumer preferences (and attitudes and perceptions) related to different dimensions of meat and beef quality characteristics. As mentioned, this work has explored consumer preferences for beef products differentiated by feed regime (e.g. Umberger et al. 2002; Sitz et al. 2005; Cox et al. 2006), tenderness (Lusk et al. 2001; Feldkamp et al. 2005), visual appearance (Killinger et al. 2004) or other characteristics (e.g. Raes et al. 2003; Oliver et al. 2006). However, much of this previous works uses data from individual consumer level studies, with a very narrow focus on a particular dimension of quality. Consequently, it is difficult to extrapolate from these narrowly focused studies to derive a conclusion that speaks to how broader improvements in beef quality impact demand for beef. Undertaking such analysis is not trivial, as there is no one measure that can adequately capture all measures of quality (especially given the subjective nature of quality in the eyes of a consumer). Nonetheless, insofar as beef grades reflect a broad measure of beef quality, it is possible to incorporate a measure of quality in the analysis.

In the absence of focusing on a specific dimension, food quality is surprisingly difficult to capture at a broad level. However, grading standards used in Canada can provide some information to consumers that might shape their demand for beef. As such, beef quality will be captured by including a variable that accounts for the proportion of beef production that is Grade 'AAA' or 'Prime' (relative to all beef graded 'A' or higher). By measuring the relationship between the proportion of beef with these grades and beef demand, it will be possible to assess how improvements in beef quality impact on beef demand.

Methods

Initial efforts focused on extending the Quadratic Almost Ideal Demand System (QUAIDS) model estimated by Cranfield (2012) to include the counts of recalls and quality measure. These efforts lead to implausibly high price and income elasticities and, in some instances, estimates that were not consistent with theory. Such results point to the need to undertake a specification search for correct functional form. To this end, Barten's general model, which nests four specific functional forms as special cases, was used rather than the QUAIDS model. The estimates from Barten's model were mixed, again with implausibly large elasticity estimates. Efforts then turned to using Deaton and Muellbauer's (1980) Linear Approximate Almost Ideal Demand System (LA/AIDS) and expanding the goods to include beef, pork and chicken and an outside good (i.e. all other goods). Further efforts were undertaken to test for structural change in the demand system. Ultimately the LA/AIDS model gave theoretically consistent results that fit the data well. As such, attention focuses on results using this LA/AIDS model

As mentioned, the estimated model includes three meats (beef, pork and chicken) and an outside good (i.e. all other goods). The budget share based system appears as:

$$w_{it} = \alpha_i + \sum_j \beta_{ij} ln(p_{jt}) + \beta_i ln\left(\frac{y_t}{P_t^*}\right) \tag{1}$$

where $ln(P_t^*) = \sum_i w_{it} ln(p_{it})$ is Stone's price index and α_i, β_{ij}, and β_i are unknown parameters. Adding-up is imposed with the following restrictions $\sum_i \alpha_i = 1$, $\sum_i \beta_i = 0$, $\sum_i \beta_{ij} = 0$ for all j, symmetry requires $\beta_{ij} = \beta_{ji}$ for all i and j, while homogeneity requires $\sum_j \beta_{ij} = 0$ for all i.

The intercept in each equation in (1) is translated by assuming it varies with a time trend, seasonality in meat demand, the 2003 BSE event, and marketing investment by cattle producers. For this study, the intercept is further translated by adding variables capturing the count of food safety recall announcements and a measure of beef quality. The translated intercepts appear as:

$$\begin{aligned} \alpha_i = \alpha_{i0} + \alpha_{it} t + \sum_k \alpha_{ik} QD_{kt} + \\ \alpha_{iBSE1} BSEDV1_t + \alpha_{iBSE2} BSEDV2_t + \alpha_{iMRKT} ln(MRKT_t) + \\ \sum_j (\alpha_{ijFS}^C + \gamma_{ijFS} \delta_{t^*}) ln(FS_{jt}^C) + \sum_j \alpha_{ijFS}^U ln(FS_{jt}^U) + \alpha_{iQUAL} ln(QUAL_t) \end{aligned} \tag{2}$$

where α_{i0}, α_{it}, α_{ik}, α_{iBSE1}, α_{iBSE2}, α_{iMRKT}, α_{ijFS}^k, γ_{ijFS} and α_{iQUAL} are parameters to be estimated, t is a time trend, QD_{kt} are seasonal dummy variables, $BSEDV1_t$ and $BSEDV2_t$ are BSE specific dummy variables, $MRKT_t$ is producer investment in marketing via check-off funded activities, FS_{jt}^C and FS_{jt}^U are counts of food safety recalls in Canada and the U.S., respectively (discussed later), and $QUAL_t$ is a measure of beef quality in Canada (discussed later). Following the literature using the counts of food safety based recall announcements, and to be consistent with the AIDS model being a second-order Taylor series expansion in natural logarithms, FS_{jt}^k and $QUAL_t$ are included in their natural logarithm. This imposes diminishing marginal effects associated with these counts and the quality measure.

Note that the count of the recalls will include those for beef, pork and chicken, as well as for non-meat, *E. coli* related recalls (e.g. a recall of a non-meat food product, such as spinach, due to possible *E. coli* contamination). Heightened awareness and sensitivity to food safety recalls has lead to changes in the Canadian food inspection system. These changes emerged largely after the Listeria based recall of ready-to-eat meats in Canada in 2008. Indeed, as will be shown in the next section, the number of recalls of beef, pork and chicken, and of non-meat foods due to possible *E. coli* contamination, increased sharply after mid-2008.

To account for potential differential relationship between demand and food safety recalls before and after 2008, the model incorporates a structural change variable, δ_{t^*}, that is interacted with the counts in Canada. Based on experimentation with the model, the term δ_{t^*} assumes a value of one from 2008:3 onwards, but zero otherwise. Given this, the relationship between demand for the various meats and recalls allows for a different relationship prior to 2008:3 (the parameters α^C_{ijFS}) and from 2008:3 onwards (the parameters $\alpha^C_{ijFS} + \gamma_{ijFS}$). As will be seen, allowing for such structure change is important in the context of Canadian beef demand.

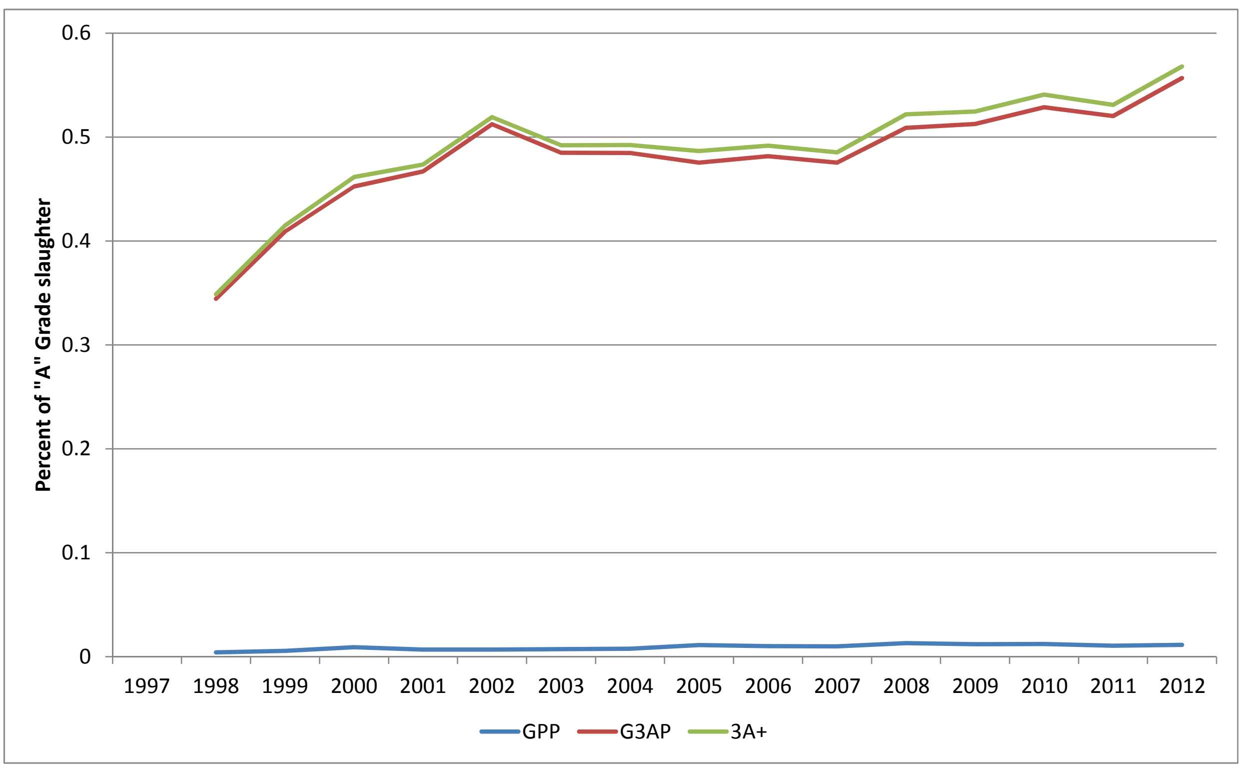
Equation (1), with equation (2) substituted in for each intercept, is estimated using the Iterated Seemingly Unrelated Regression (ISUR) estimator. Furthermore, since equation (1) is a singular system, the last equation (other goods) is dropped during estimation.

Data

As this analysis extends Cranfield's (2012) beef demand model, it uses the same data set used therein. Briefly, data are observed on a quarterly basis, spanning the time period 1998 Q1 to 2010 Q3. Cranfield (2012) contains a more complete description of the relevant economic and non-price data.

Added to this data are recall and beef quality measures. The measure of beef quality (albeit a proxy for quality) is the proportion of beef that is graded at least 'A' that is either 'Prime' or 'AAA'. Monthly volumes of beef produced under four different 'A' Grades (i.e. 'Prime', 'AAA', 'AA' and 'A') were provided by CANFAX for the period 2000 to 2013. For the purposes of this analysis, these data were aggregated to a quarterly basis. To extend this series backwards to 1998, the annual share of beef in the 'Prime' and 'AAA' classes in 1998 and 1999 was used to infer quarterly values in those years (i.e. each year's value was used as the measure of beef quality in the respective quarter). Figure 1 shows the trend in the percent of at least 'A' grade beef that is 'Prime' or 'AAA' classes (the series G3AP) increased during the study period.

Figure 1. Proportion of Canadian federally inspected slaughter grades AAA (*3A+*) or Prime (*GPP*)



The count of the recall data for Canada was complied using data gathered from the

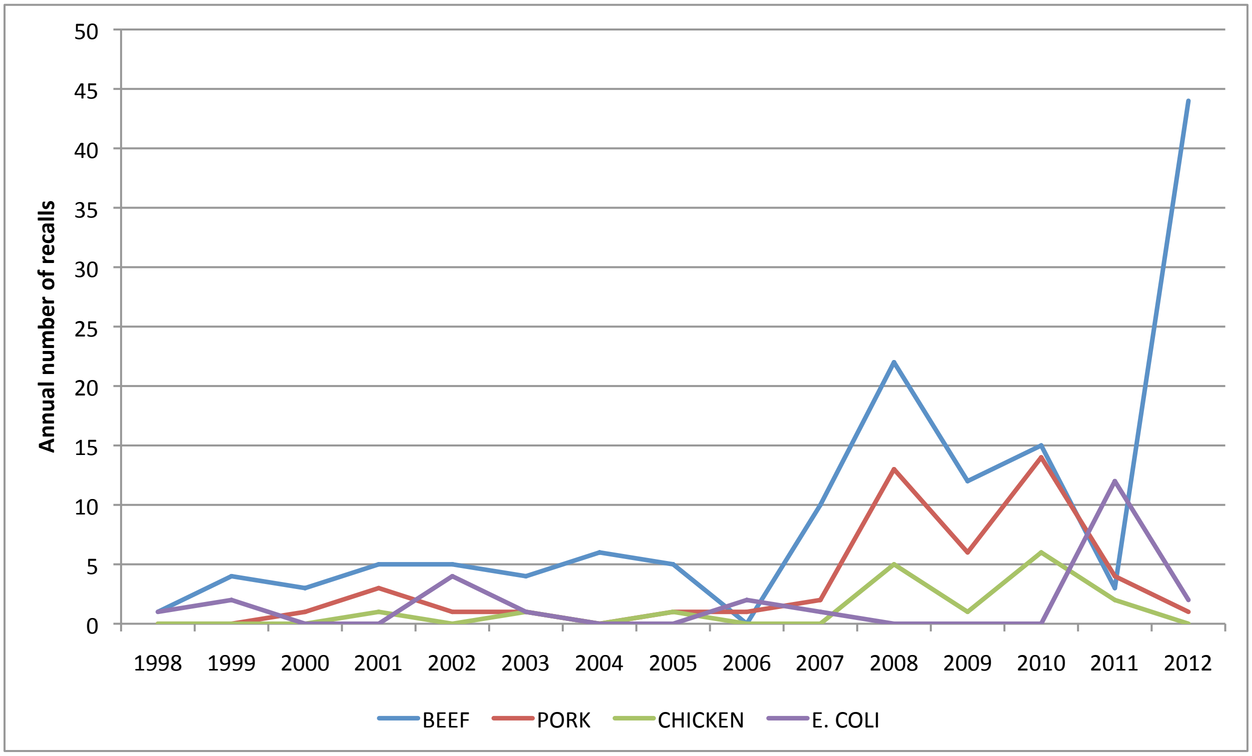
Canadian Food Inspection Agency's (CFIA) 'Food Recalls and Allergy Alerts' webpage. These data were collected for the period January 1997 (the earliest point in time at which archived recalls are available) to December 2012. For each month, the CFIA database was searched for biologically (i.e. microbiologic or viral contamination) based recalls of food. Once these recalls were identified, the relevant announcements were printed and scrutinized for further detail. Each recall was examined to determine whether the recall related to beef, pork, chicken or some other food. If the recall related to food other than beef, pork or chicken, it was examined to determine whether it was related to possible *E. coli* contamination. For each meat and each month, the number of recalls was tallied, as was the number of non-meat, *E. coli* related recalls. Recalls of processed food products that explicitly listed anyone of the three meats were also included in the count for that meat product. Announcements that expanded the scale or scope of a previous recall announcement were treated as a separate recall to allow for the fact that expansions could be viewed as *de novo* announcements. However, updates, corrections and clarifications that did not expand the scale or scope of a recall were not included in the count. An identical procedure was used to gather recall data for the United States. The U.S. data were collected from the Food Safety and Inspection System (FSIS) website, and over a period January 1994 to December 2012. Note that the recall counts included Class I, II and III recalls for the U.S. and Canada (see the appendix for details on these classes). For both Canadian and U.S. recall data, the relevant monthly counts were aggregated to a quarterly basis. Since these variables are included in natural logs in the model, and there were quarters were the count of the relevant recalls equalled zero, one was added to each recall series and the natural log taken (see Tonsor et al. 2010).

It is noted that the Public Health Agency of Canada (PHAC) has launched a website with information about food safety issues that might affect public health. The recalls included in the PHAC website are not used here. Several reasons underlie this. First, the recalls PHAC would list on their website originate from the CFIA, so by going directly to the CFIA website, this information is obtained from a primary source. Second, the PHAC website does not archive its alerts in a manner suitable to data recovery, making very difficult to develop a time series of counts. While it is recognized that the PHAC site includes U.S. recalls that might affect Canadians, by including the U.S. recalls issued through FSIS, the model does capture the potential spillover effect from the U.S. to Canada

Figures 2 and 3 plot the Canadian and U.S. recall counts over time. These figures are highly informative. During the period under study, there were typically more Canadian recalls of beef than pork or chicken. A marked increase in recalls of all meats in Canada in 2008 is noted (and expected given heightened scrutiny of meat products in the shadow of the Listeria recall). The large and sizeable spike in Canadian beef recalls in 2012 relate to the XL Foods recall in Fall 2012.

The analysis does not include time periods during which the XL Foods recall occurred. Two reasons underlie this. First, the data needed to construct the supply-disposition tables required for the quarterly per capita consumption series were not all available. As well, not all the price and income data needed to estimate the model into 2012 were yet available. Secondly, the XL Foods recall was so large, and garnered such widespread attention, that it stands out in the context of meat recalls in Canada. Because of this, it is possible that the XL Foods recall could sway the results in a manner that does not reflect the history before the XL Foods recall.

Figure 2. Annual number of recalls across meat types and non-meat E. coli related recalls, Canada



The U.S. recall data are also informative. As with Canada, there were more beef recalls than pork or chicken recalls in the U.S. Also evident is a rising trend in non-meat, *E. coli* based food recalls in the U.S., particularly since 2008. To provide a more complete picture of the grading and recall data, Table 1 shows the mean and standard deviation (in parentheses) of the count of recalls across products and *E. coli*, in Canada and the United States. This table reinforces the higher number of beef recalls than pork or chicken recalls.

Figure 3. Annual number of recalls across meat types and non-meat E. coli related recalls, USA

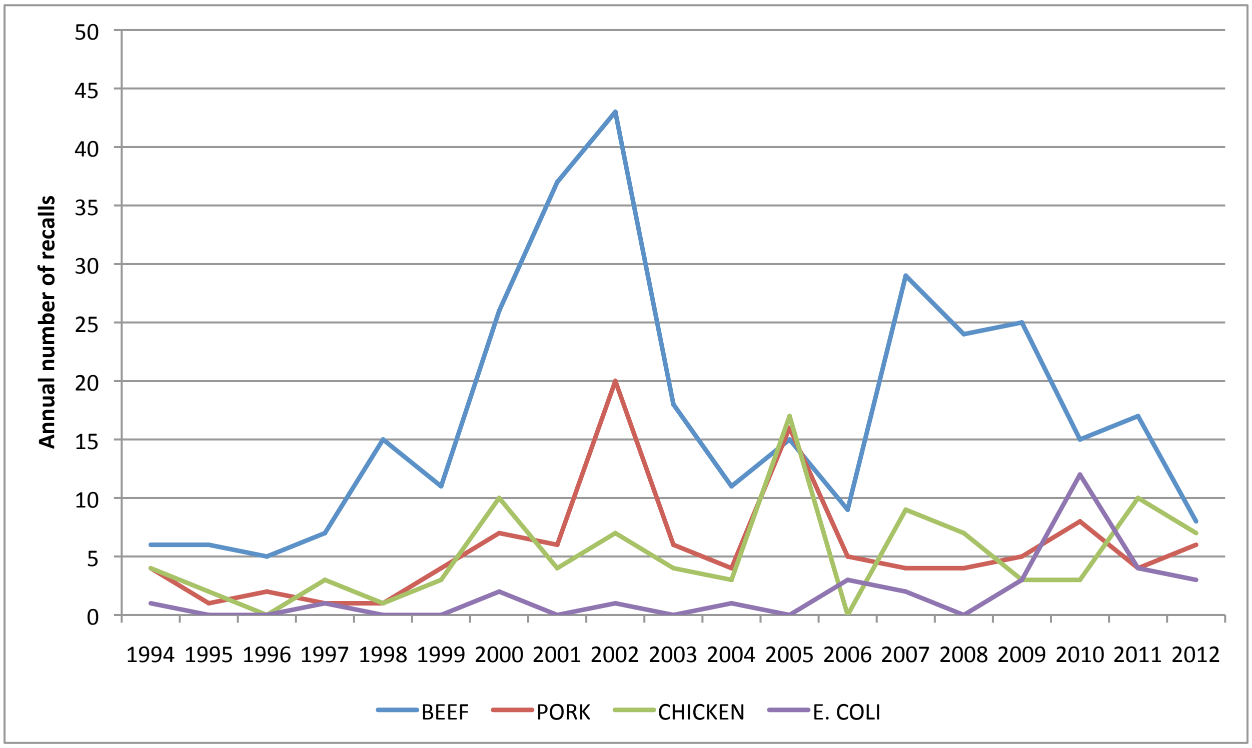


Table 1: Mean and standard deviation of recalls of beef, pork and chicken, and non-meat products (due to *E. coli* contamination, Canada and the United States 1998-2012)

	Canada	U.S.
Beef	2.172	4.303
	(3.453)	(3.374)
Pork	0.750	1.421
	(1.652)	(1.569)
Chicken	0.266	1.276
	(0.597)	(1.466)
E. coli	0.391	0.434
	(1.018)	(1.204)

Figures 4 and 5 plot quarterly per capita beef disappearance in Canada against the count of the number of recalls, along with a trend line. The trend line in Figure 4 suggests that quarters in which there was at least one recall typically had lower beef demand than quarters in which no recalls occurred. A similar occurrence is noted when disappearance is plotted against the number of recalls of non-meat food products in Canada due to possible *E. coli* contamination, although the trend is more subtle than in Figure 4.

Figure 4. Per capita beef disappearance in Canada plotted against number of beef recalls in Canada

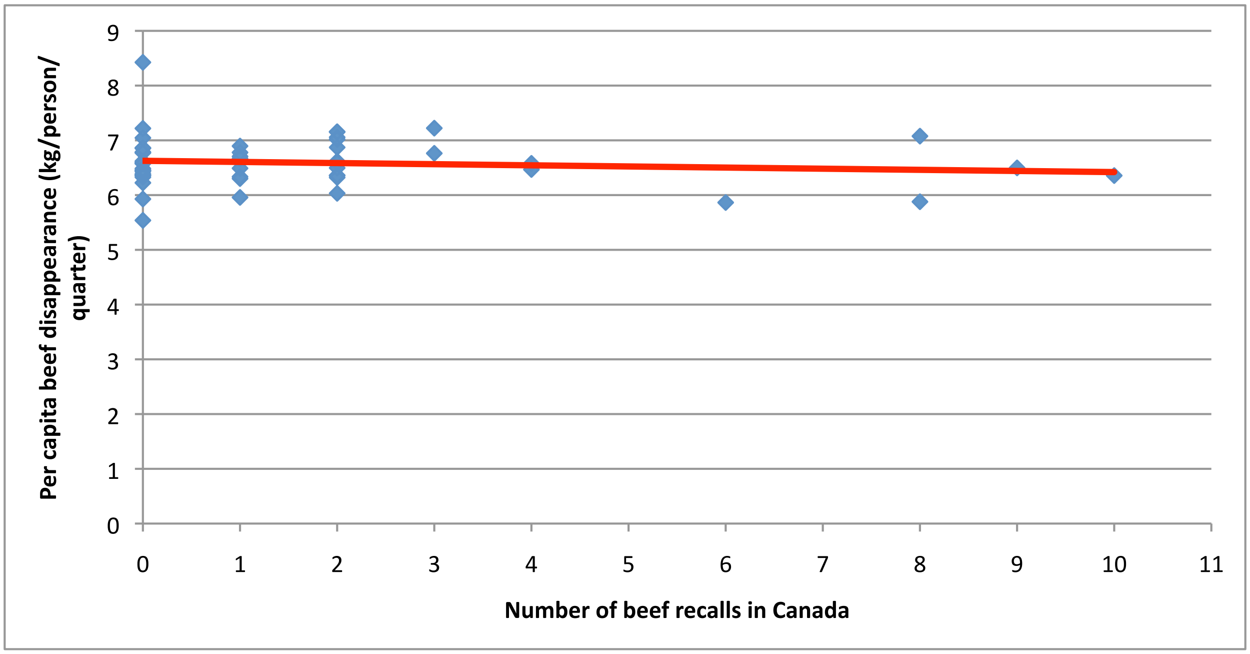
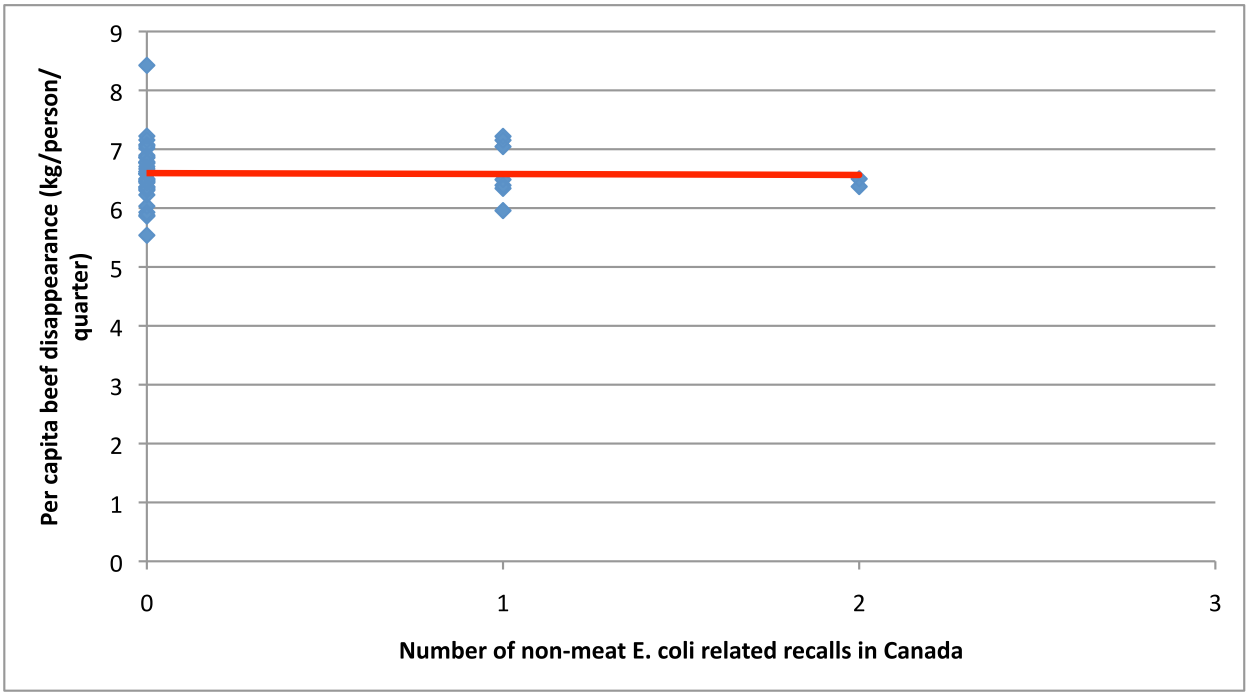


Figure 5. Per capita beef disappearance in Canada plotted against number of non-meat, *E. coli* related food recalls in Canada



Figures 6 and 7 also plot per capita Canadian beef disappearance, but against the count of the number of U.S. beef recalls (Figure 6) and the number of non-meat recalls in the U.S. due to possible *E. coli* contamination. The trend line in Figure 6 suggests a very limited relationship between Canadian beef demand and the number of beef recalls in the U.S. However, a downward trend between Canadian beef demand and non-meat recalls in the U.S. due to possible *E. coli* contamination is noted in Figure 7.

Figure 6. Per capita beef disappearance in Canada plotted against number of beef recalls in the U.S.

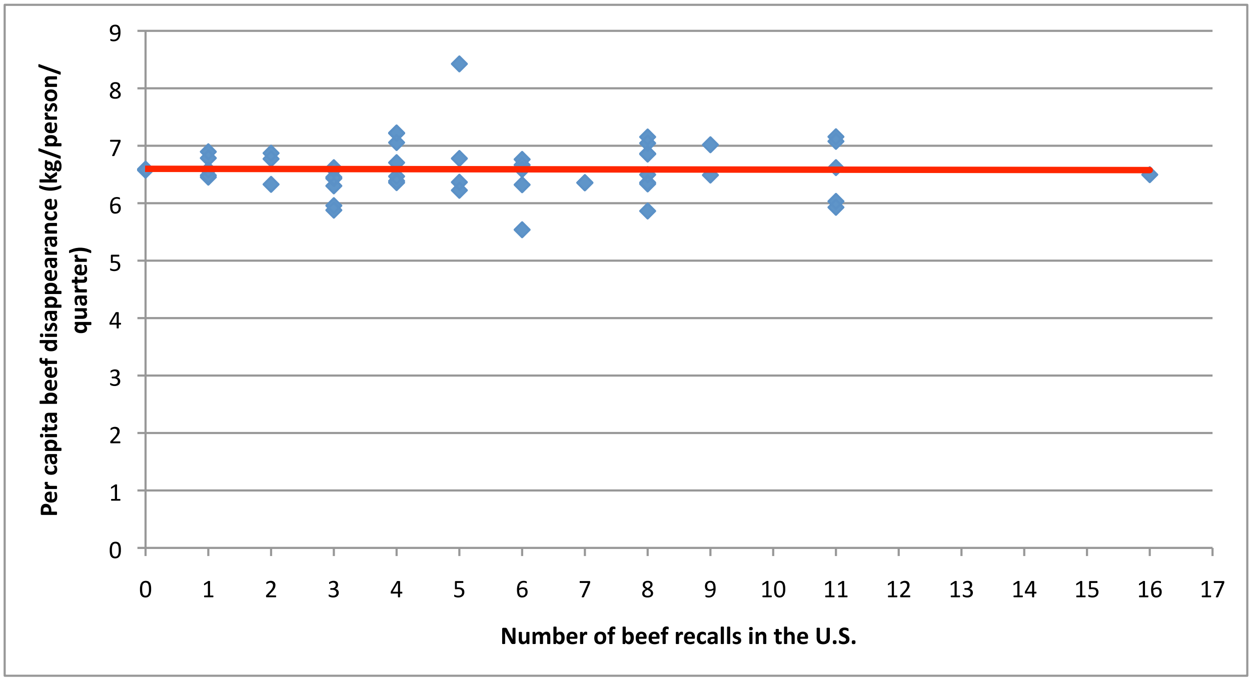
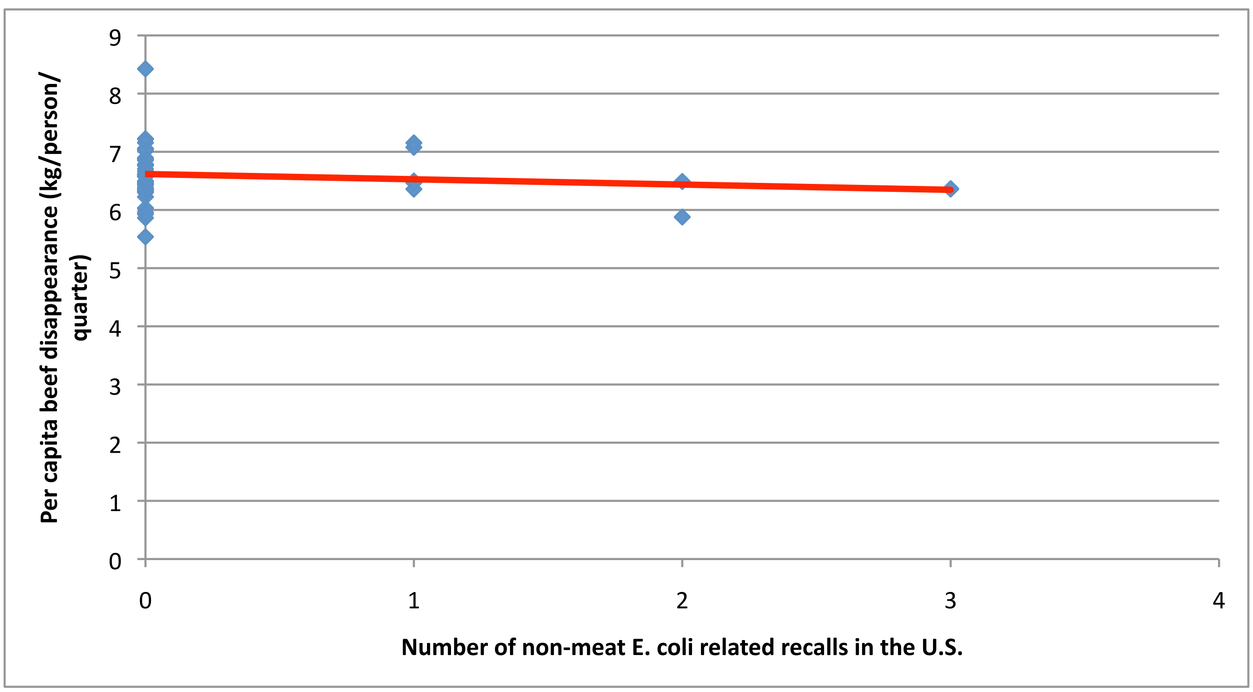


Figure 7. Per capita beef disappearance in Canada plotted against number of non-meat, *E. coli* related food recalls in the U.S.



Results

This section provides discussion of the results from the econometric estimation of the LA/AIDS model specified above. Prior to discussing results, it is important to note that the joint effect of the quality and recall variables on demand can be assessed via tests of restrictions on parameters related to these variables; results of such tests are reported below. Discussion then focuses on the estimated parameters and their significance. Based on these parameters, income and price elasticities are then reported and discussed, followed by the elasticities of demand for the three meats with respect to the quality and recall variables. The beef equation from the estimated model is then simulated to assess the change in beef demand arising from an additional recall.

It is important to note that given the large number of recall variables included in the analysis, and the relatively short time period covered by the data, that it was not possible to included lagged values of the recall variables without compromising the confidence one can have in the resulting estimates. In particular, the inclusion of a one-period lag in all the recall variables requires estimation of 33 additional parameters. Incorporating current period and lagged values of the recall variables would simply ask too much of the data and could lead to less precise estimates of the impact of the economic and non-economic variables. As such, the model is estimated without lagged recall variables and the resulting elasticities should be viewed as long-run elasticities that reflect a within quarter response to recalls.

Estimation results

Initial estimates allowed for structural change between budget shares and the Canadian recall variables for beef, pork and chicken. Wald tests were undertaken to determine if the structural change parameters in each meat's demand equation were jointly significant. Results suggest significant structural change in the relationship between demand for beef and the number of Canadian recalls of beef, pork and chicken ($p\text{-value}<0.001$). However, the structural change parameters for the Canadian meat recall variables were not jointly significant in the pork (p-value=0.84) and the chicken equations of the model (p-value=0.11). As such, the structural change parameters were not included in the equations for pork and chicken, but were retained in the beef equation.

Prior to discussing results, note that Table 2 shows the results of the tests related to joint null hypotheses on the quality and recall parameters. Taken together, the quality and recall variables (both Canadian and U.S.) have jointly significant effects on demand for meats in Canada. This suggests that ignoring these effects could bias the resulting estimates. To understand better how the individual recall and quality variables affect demand, joint nulls on subsets of these parameters were tested. The null that the quality variables do not have jointly significant effects was rejected, as was the null that the recall effects (i.e. both Canadian and U.S.) had no joint effect. The impact of country specific recall variables was also explored and suggests that Canadian quality and recall effects were jointly significant, as were U.S. recall effects. Taken together, results suggest that the Canadian recall variables for beef, pork and chicken had significant effects, as did the U.S. recall variables for beef, pork and chicken.

Table 2: Results of joint null hypothesis tests on recall and quality parameters

Joint null hypothesis	Test statistic	p-value
No quality or recall effects (i.e. $\alpha_{iQUAL} = \alpha^C_{ijFS} = \alpha^U_{ijFS} = 0$ for all i and j)	131.13	<0.001
No quality effects (i.e. $\alpha_{iQUAL} = 0$ for all i)	20.39	<0.001
No recall effects (i.e. $\alpha^C_{ijFS} = \alpha^U_{ijFS} = 0$ for all i and j)	98.97	<0.001
No Canadian recall effects (i.e. $\alpha^C_{ijFS} = 0$ for all i and j)	51.08	<0.001
No U.S. recall effects (i.e. $\alpha^U_{ijFS} = 0$ for all i and j)	59.09	<0.001

Table 3 shows the estimated parameters from the model, their t-statistics and model fit statistics. All three equations fit the data well, with r-squared values ranging from 0.88 (for beef) to 0.96 (for pork). As well, Durbin-Watson statistics suggested serial correlation was not present in the errors (an ad hoc visual examination of the error terms was also undertaken to confirm this). Twenty-nine of 63 estimated parameters were statistically significant at the ten percent level or better.

Table 3: ISUR parameter estimates and t-statistics

	Beef		Pork		Chicken	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Intercept	0.0287	0.50	0.1029	2.10	0.0499	1.83
Q1	0.0005	0.94	0.0004	0.86	-0.0003	-1.50
Q2	0.0003	1.25	-0.0002	-0.97	-0.0001	-0.35
Q4	-0.0006	-2.01	0.0008	2.84	-0.0003	-2.52
Time	0.0001	0.14	-0.0001	-0.88	0.0001	1.10
BSE1	0.0003	0.72	-0.0010	-2.57	0.0001	0.84
BSE2	0.0034	7.59	-0.0009	-2.15	-0.0002	-1.02
Beef marketing	0.0001	0.62	-0.0001	-0.84	0.0002	3.09
Beef price	0.0097	4.26				
Pork price	0.0014	0.81	0.0062	3.99		
Chicken price	-0.0013	-1.18	0.0016	1.68	0.0036	2.72
Income	-0.0048	-0.75	-0.0135	-2.44	-0.0057	-1.91
Quality	-0.0023	-2.29	-0.0022	-2.62	0.0013	3.33
CND beef recall	0.0005	3.61	-0.0001	-0.46	0.0001	0.46
CND beef recall s.c.[a]	-0.0009	-4.74				
CND pork recall	-0.0001	-0.02	-0.0004	-3.15	0.0001	1.49
CND pork recall s.c.	0.0002	0.85				
CND chicken recall	-0.0007	-2.40	0.0005	2.69	-0.0001	-0.04
CND chicken recall s.c.	0.0011	2.48				
CND *E. coli* recall	0.0003	1.09	-0.0002	-0.70	0.0001	0.85
US beef recall	0.0001	0.45	0.0004	3.36	0.0001	1.31
US pork recall	-0.0002	-1.32	-0.0003	-2.44	-0.0001	-0.39
US chicken recall	-0.0001	-0.57	-0.0002	-1.69	0.0001	0.32
US E. coli recall	-0.0006	-3.15	0.0001	0.84	0.0001	1.37
R-squared	0.880		0.963		0.848	
D.W. stat.	1.90		2.21		2.06	

a. s.c. denotes structural change parameters

Focusing on the quality and recall variables, the beef quality variables were significant in all three meat demand equations. The coefficient capturing the count of Canadian beef recalls (and the structural change term for this count) was significant in the beef demand equation, but not in the pork or chicken demand equations. Possible sources of structural change between Canadian beef demand and recalls could include the emergence of heightened awareness of recalls in Canada in the aftermath of BSE, large scale recalls of beef in the U.S., and the 2008 Listeria recall. Information flows are also important. In particular, social media and consumer access to recall notifications via, for example, Twitter and email feeds from CFIA, puts this information more readily in the hands of the consumer compared to pre-social media periods. While it is not possible to discern the impact of one possible cause, the net effect is to alter the relationship between beef demand and beef recalls. The count of Canadian pork recalls had a significant effect in the pork equation, but not in the beef and chicken equations. The count of Canadian chicken recalls was significant in the beef and pork equations, but not in the chicken equation. None of the coefficients related to Canadian recalls of non-meat food arising from possible *E. coli* contamination were statistically significant.

Amongst the variables capturing the impact of U.S. recalls, beef, pork and chicken recalls all had a statistically significant impact in pork demand in Canada, but not on beef or chicken demand. Interestingly, the count of non-meat *E. coli* based recalls in the U.S. only had a significant effect in the beef demand equation. This suggest potential negative spillovers on Canadian beef demand arising from recalls of non-meat food in the U.S. due to possible *E. coli* contamination. Recognize that while the parameters are of interest, their values do not tell us much in terms of a volumetric impact of recalls on demand for the three meats. To explore this issue, elasticities of demand for the quality and recall variables, along with price and income variables, were calculated.

Table 4 shows the mean value and t-statistic for the uncompensated price and income elasticities. While not the primary focus in this study, note that own-price effects are all negative, as expected, and that beef and chicken are income normal goods, while pork is an income-inferior good (albeit, the income elasticity for pork was not significant). Note too, that the own-price elasticities of demand for the three meats are all inelastic, meaning prices can change a great deal before quantity demanded shows larger changes.

Table 4: Summary statistics of the estimated uncompensated price and income elasticities[a]

	Beef	Pork	Chicken	Other	Income
Beef	-0.158	0.120	-0.113	-0.435	0.585
	(-0.849)	(0.837)	(-1.166)	(-0.662)	(1.077)
Pork	0.212	-0.118	0.233	0.558	-0.886
	(0.913)	(-0.788)	(1.783)	(0.616)	(-1.075)
Chicken	-0.213	0.273	-0.397	0.295	0.042
	(-1.133)	(1.729)	(-1.837)	(0.420)	(0.091)
Other	-0.010	-0.010	-0.004	-1.001	1.025
	(-5.051)	(-5.811)	(-2.605)	(-80.145)	(96.804)

a. t-statistics are shown parentheses

Table 5 shows the compensated price elasticities from the model (again, showing the mean value and t-statistics). All own-price effects are negative (as expected), with the three meats still having inelastic responses to own-price. Cross-price effects suggest that beef and pork, and pork and chicken are net substitutes, while beef and chicken are net complements.

Table 5: Summary statistics of the estimated compensated price elasticities[a]

	Beef	Pork	Chicken	Other
Beef	-0.151	0.125	-0.109	0.135
	(-0.804)	(0.866)	(-1.121)	(0.814)
Pork	0.202	-0.124	0.228	-0.306
	(0.866)	(-0.809)	(1.731)	(-1.115)
Chicken	-0.213	0.273	-0.397	0.336
	(-1.121)	(1.731)	(-1.819)	(1.320)
Other	0.002	-0.002	0.002	-0.002
	(0.814)	(-1.115)	(1.320)	(-0.606)

a. t-statistics are shown parentheses

Of more interest are the elasticities of meat (and in particular beef) demand with respect to the quality and recall variables. Table 6 shows the elasticity of each meat with respect to the beef quality variable. Recall the latter is captured using the proportion of at least Grade 'A' beef that is graded as 'AAA' or 'Prime'. All three quality elasticities are statistically significant. The elasticity of demand for beef in Canada with respect to the beef quality variable is about -0.2. This means a one percent increase in beef quality in Canada leads to a 0.2 percent reduction in beef consumption. Such a result may seem counterintuitive. Recognize, however, that such a relationship could reflect a quality-quantity trade-off on the part of consumers. When buying a better quality cut of beef, consumers could be buying less quantity, a reflection of economizing on the part of consumers (i.e. a higher unit price for a better cut of beef leads to consuming less beef). As beef quality increases, results suggest that pork demand also falls, while chicken demand increases. It is noteworthy that the inverse relationship between beef demand and beef quality was apparent in the different versions of the model that were estimated prior to developing the present model; this suggests a robust relationship exists between beef demand and quality.

Table 6: Summary statistics of the estimated beef quality elasticities[a]

Meat:	Elasticity
Beef	-0.198
	(-2.293)
Pork	-0.305
	(-2.622)
Chicken	0.212
	(3.333)

a. t-statistics are shown parentheses

Table 7 shows the elasticity of demand for each meat in Canada with respect to the Canadian recall variables. Recall that for beef, structural change was found in this relationship, consequently the table shows the recall elasticities before and after structural change.[3] Focusing on beef demand, the elasticities shown below suggest a positive relationship between beef demand and the number of beef recalls prior to structural change. This is an unexpected result. However, two issues may explain this relationship. First, prior to structural

[3]Even though pork and chicken recall effects were not affected by structural change, the table reports the recall elasticities for all meats before and after structural change for beef. It does so to illustrate whether the magnitude of the pork and chicken recall elasticities differed substantially across the two time periods.

change there were fewer recalls of beef than after structural change occurred. That there were so few beef recalls, coupled with an unexpected sign, suggest the positive elasticity of beef demand with respect to beef recalls is a spurious relationship. Another factor that cannot be overlooked, is the in the aftermath of BSE, many Canadian consumers increased their consumption of beef, and as such, the measured relationship could reflect a response to a crisis in the beef industry that did not actually include a food safety based recall of beef. The elasticity of beef demand with respect to Canadian recalls of pork and chicken were negative, suggesting a spillover effect of recalls from these meats onto the beef sector. Also unexpected is the positive (but insignificant) relationship between beef demand and recalls of non-meat food products due to *E. coli* contamination.

Table 7: Summary statistics of the estimated Canadian meat recall elasticities before and after structural change[a]

Before structural change				
	Beef	Pork	Chicken	*E. coli*
Beef	0.042	-0.001	-0.058	0.023
	(3.612)	(-0.022)	(-2.400)	(1.091)
Pork	-0.006	-0.049	0.071	-0.020
	(-0.456)	(-3.154)	(2.692)	(-0.702)
Chicken	0.004	0.013	-0.001	0.014
	(0.460)	(1.490)	(-0.041)	(0.849)
After structural change				
	Beef	Pork	Chicken	*E. coli*
Beef	-0.037	0.020	0.036	0.024
	(-2.218)	(1.167)	(1.129)	(1.091)
Pork	-0.009	-0.071	0.101	-0.028
	(-0.456)	(-3.154)	(2.692)	(-0.702)
Chicken	0.004	0.012	-0.001	0.013
	(0.460)	(1.490)	(-0.041)	(0.849)

a. t-statistics are shown parentheses

Nonetheless, after structural change in the relationship between beef demand and the Canadian recalls, the signs of some of these recall elasticities changed. Notably, after structural change, the elasticity of beef demand with respect to the count of Canadian beef recalls was negative and significant. Moreover, the value of this elasticity suggests that a one-percent increase in recalls leads to a 0.037 percent decline in beef demand. Such an estimate is on par with a recently reported elasticity of U.S. beef demand with respect to U.S. beef recalls in Tonsor et al. (2010); their measured beef recall elasticity in the long-run was -0.023. As well, the elasticity of beef demand with respect to Canadian pork and chicken recalls were positive (as expected), but not significant. Lastly, structural change did not affect the relationship between beef demand and the recall of non-meat foods in Canada due to possible *E. coli* contamination (i.e. this elasticity was again positive, but not significant).

Table 8 shows the elasticities of Canadian meat demand with respect to the U.S. recall variables. Focusing attention on beef, one sees that the impact of U.S. meat recalls on Canadian beef was not statistically significant. However, it is interesting that the impact of U.S. recalls of non-meat foods because of possible *E. coli* contamination did have a significant effect on Canadian beef demand, and this effect was negative. A one-percent increase in recalls of U.S. non-meat foods arising from possible *E. coli* contamination leads to a 0.055 percent reduction in Canadian beef demand.

Table 8: Summary statistics of the estimated U.S. meat recall elasticities[a]

	Beef	Pork	Chicken	E coli
Beef	0.005	-0.017	-0.006	-0.055
	(0.447)	(-1.325)	(-0.565)	(-3.151)
Pork	0.056	-0.042	-0.028	0.020
	(3.365)	(-2.436)	(-1.687)	(0.838)
Chicken	0.012	-0.004	0.003	0.017
	(1.314)	(-0.388)	(0.324)	(1.366)

a. t-statistics are shown parentheses

Simulation analysis

To help put the econometric results in a better light, the estimated beef demand equation was used to simulate the effect of one additional beef recall in Canada. For this purpose, and to reflect more recent history, the equation was simulated during the period where structure change was noted (i.e. 2008:3 to 2010:3). This simulation allows one to see what impact an additional recall would have on beef demand and the value of retail beef sales. To illustrate the range of effects, the simulations enable examination of an additional recall in each quarter of the period 2008:3 to 2010:3.

During the simulation period, one additional recall of beef in Canada lead to an average reduction in Canadian beef demand of 2.26 million kilograms per quarter. This volume reduction ranged from a low of 0.71 million kg to a high of 5.74 million kg (depending on the quarter in which the additional recall occurred). On a value basis, the average reduction in retail beef expenditure in Canada was $26.5 million per quarter (with a range between a $8 million and $67 million reduction). On a proportional basis, the impact of one additional recall was about one-percent of retail value. What is important to note is that since the model assumes the count of recalls enters in natural logs, that consumer's response to an additional recall exhibits diminishing marginal effects. Consequently, the impact of one additional recall is very large in quarters where there were no (or a low number) of recalls, but smaller in quarters in which there were already a number of beef recalls.

Conclusions

The analysis in this paper sought to answer to two basic questions. First, have improvements in beef quality affected consumer demand for beef in Canada? Second, have recalls of beef, and meats in general, affected consumer demand for beef in Canada. To answer these questions, a meat demand system was estimated. The model, which built upon Cranfield (2012) included beef, pork and chicken, as well as an outside good representing all other goods. Beef quality was captured using the percent of at least 'A' grade beef that was in the 'AAA' or 'Prime' categories. Meat recalls were captured using the count of recalls of beef, pork and chicken in Canada, as well as recalls of non-meat foods that were based on potential *E. coli* contamination. To account for potential spillover effects from the United States, the counts of U.S. recalls for these meats, as well as non-meat *E. coli* based recalls, were also included in the model.

The model was estimated using a Linear Approximate, Almost Ideal Demand System, and estimated with quarterly data from 1998 to 2010. Improvements in beef quality had an inverse relation with beef demand in Canada. While seemingly counterintuitive, this relationship could be explained by a quantity-quality trade-off. In particular, when buying a better quality cut of beef, consumers could be buying less quantity, a reflection of economizing on the part of consumers. Results also point to structural change in the relationship between beef demand in Canada and the count of beef, pork and chicken recalls. Prior to mid-2008, the relationship between beef demand and beef recalls was positive. After mid-2008, this relationship became negative and suggested that a one-percent increase in beef recalls would lead to a 0.037 percent decrease in beef demand. Interestingly, there was no statistically measurable relationship between beef demand in Canada and the count of non-meat, *E. coli* based recalls in Canada. As well, U.S. recalls of beef did not have a statistically measurable relationship with Canadian beef demand. However, a one-percent increase in U.S. recalls of non-meat foods because of possible *E. coli* contamination did have a measurable relationship with Canadian beef demand. In particular, a one-percent increase in U.S. *E. coli* based recalls of non-meat foods lead to a 0.055 percent reduction in Canadian beef demand.

To understand better the impact of a Canadian recall of beef, the beef equation from the model was simulated over the period 1998:Q3 to 2010:Q3, assuming there was one additional recall in each quarter. The simulation was structured in this manner to explore how one additional recall would affect demand at different points in time. On average, over this time period, one additional beef recall in Canada lead to a 2.26 million kilogram reduction in beef demand. In value terms, this is equivalent to about $26 million at the retail level, or about one-percent of consumer beef expenditure.

While these results are useful insofar as being able to estimate the impact of an additional recall, the analysis does have a number of limitations. First, the recall data are only counts of the recalls, they do not reflect the volume recalled. Arguably, the volume recalled could be used in place of the counts, or as a means of adjusting the counts to reflect scope of the recall. Second, the analysis is limited by availability of historical data. In particular, it was not possible to obtain recalls into the mid 1990s and earlier. Incorporating such temporal dimensions might be important in being able to more accurately measure the impact of recalls, and to incorporating dynamic responses to recalls. Likewise, the analysis does not include data beyond 2010; one reason for this is that some of the data were not available. More substantially, data limitations prevented inclusion of the time period during which the 2012 XL Foods beef recall occurred. However, even if these data were available, the scale of the XL Foods recall was such that it might heavily skew the results that reflect the broader trend over time. Lastly, the analysis does not reflect consumer confidence in the foods system and meat sector. Clearly, incorporating consumer confidence would be a useful step forward insofar as assessing the impact of recalls on meat demand in general, and beef demand in particular.

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Appendix: Types of recall classes in Canada and the U.S.

Both Canada and the U.S. currently differentiate food safety related recalls across three types, or classes. In Canada, the classification scheme was not used until 2011. Nonetheless, the CFIA defines these classes of recalls as follows (these definitions are stated directly from the CFIA website):

- 'Class I' (high risk): is a situation in which there is a reasonable probability that the use of, or exposure to, a violative product will cause serious adverse health consequences or death
- 'Class II' (moderate risk): is a situation in which the use of, or exposure to, a violative product may cause temporary adverse health consequences or where the probability of serious adverse health consequences is remote
- 'Class III' (low or no risk): is a situation in which the use of, or exposure to, a violative product is not likely to cause any adverse health consequences.

In the United States, the FSIS defines these classes as follows (these definitions are stated directly from the FSIS website):

- 'Class I': This is a health-hazard situation where there is a reasonable probability that the use of the product will cause serious, adverse health consequences or death. Examples of a Class I recall include the presence of pathogens in ready-to- eat meat or poultry products, or the presence of E. coli O157:H7 in raw ground beef.
- 'Class II': This is a health-hazard situation where there is a remote probability of adverse health consequences from the use of the product. Examples of a Class II recall include the presence in a product of very small amounts of undeclared allergens typically associated with milder human reactions, e.g., wheat or soy or small sized, non-sharp edged foreign material in a meat or poultry product.

- ‘Class III’: This is a situation where the use of the product will not cause adverse health consequences. An example of a Class III recall is the presence of undeclared, generally-recognized as safe, non-allergenic substances, such as excess water in meat or poultry products.