Canadian Beef Demand Elasticity Study - Final report*

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Abstract

A quarterly, weakly-separable, Quadratic, Almost Ideal Demand System is estimated for beef, pork and chicken in Canada. The restrictions that would lead to the less flexible Almost Ideal Demand System were rejected at the five per cent level. Results for the first stage model (of the two-stage budgeting process implied by weak separability) indicated that demand for the meat group is inelastic, with an own-price elasticity of -0.24. Demand for beef in Canada was inelastic during the period under study. The conditional, uncompensated own-price elasticity of demand was -0.83, while the unconditional, uncompensated elasticity of demand for beef was -0.43. The latter was almost identical to the estimate reported by Tonsor et al (2011) for the U.S. (and based on a different model). Demand for beef in Canada appeared to become more inelastic prior to discovery of BSE in Canada, but since then beef demand has become less inelastic, although the change is subtle.

Keywords: Consumer demand, beef, Canada

JEL Codes: D12, Q11

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Introduction

Numerous events and regulatory changes appear to have influenced consumer and international demand for Canadian beef. The discovery of Bovine Spongiform Encephalopathy (BSE) in 2003 closed borders to Canadian beef exports and created a captive market for domestically produced beef. While beef demand increased in 2003 as consumers supported the Canadian beef industry, demand for beef in Canada has has generally declined over the long-run. It is expected that negative media attention and strong competition from competing meats has impacted how consumers respond to beef. International demand for Canadian beef continues to be impacted by limited market access and competition from other exporting countries as Canada slowly regains market share. These changes in domestic and international consumer perceptions need to be reflected in updated demand models.

However, research undertaking to estimate the elasticity of various meats in Canada is limited. While the U.S. and Canadian beef markets have historically been integrated, U.S. demand studies cannot be expected to be accurate at this point due to barriers to trade and regulatory changes (i.e. disposal of specified risk material in Canada). In addition, demand studies in the U.S. imply changing trends with time, with beef demand becoming increasingly inelastic. Currently there is no Canadian study to show if a similar trend is happening in the Canadian market. What is more, the published Canadian meat demand analysis (e.g. Eales 1996, Lambert et al. 2006) uses data that does not cover the post-BSE environment.

Moreover, little work has been undertaken to measure the elasticity of demand for Canadian beef in international markets, and what does exist is somewhat dated (e.g. Epp 1990). What is more, our understanding of differences in beef demand elasticities along the supply chain is rather limited and reflects a pre-BSE market environment (e.g. Cranfield and Goddard 1999). As such, updated retail beef demand elasticities would provide an indicator of current trends for domestic use, and contribute to a more information-based policy making environment.

The importance of understanding these beef demand elasticities is underscored by changes in consumer perceptions and willingness to pay for different sources of animal-protein. Furthermore, rising grain prices are expected to be passed through the supply chain to retail beef prices, where consumers' response to higher prices makes it important to have updated meat demand elasticities in order to evaluate overall performance of the Canadian beef sector. Therefore, measuring the elasticity of demand for Canadian beef is important in evaluating the performance of the domestic industry and placing this performance in a relative context in the international market place.

As such, this research aims to estimate the elasticity of beef demand at the retail level in Canada. This aim leads to the following research objectives:

1. Identify the important drivers of demand for beef, including non-economic drivers of

demand (e.g. impact of BSE, advertising and promotion)

2. Develop a model that will enable estimation of the retail demand elasticity for beef in Canada

3. Estimate the elasticity of retail beef demand in Canada with respect to the price of beef, price of related goods (e.g. substitution elasticities), income and other drivers of retail demand identified above.

To undertake this analysis, a meat demand system for Canadian will be estimated; this system will include demand for beef, pork and chicken. [1] The model will be estimated using quarterly data from 1998 to 2010, and will take explicit account of the possible impact of discovery of BSE infected cattle in Canada in May 2003 and investment of beef-cattle producer check-off funds in beef marketing activities in Canada.

Previous Research

To place this research in a context of other research, it is important to note that economists have spent considerable time and effort modelling consumer demand for final goods and services. Much of this analysis has used empirically tractable demand systems, including the Linear Expenditure System, the Rotterdam model and the Almost Ideal Demand System (AIDS). However, few of the applied demand studies for food products go beyond the AIDS and/or Rotterdam models. Such inertia is problematic given the limitations of the models used. The AIDS model is a rank two-demand system, while the Rotterdam model has constant marginal budget shares. Such weaknesses limit the application of these models to data sets that show wide variation in expenditure or price levels. Moreover, recently developed demand systems offer more flexible responses to price and income changes. In this regard, scope exists to assess performance of these more general models when modelling consumer demand for meat (and beef in particular) in Canada.

While Deaton and Muellbauer's PIGLOG preferences (which leads to the AIDS model) have become the mainstay of applied demand analysis in agricultural economics, it is not without fault, as indicated above. Because of this, others have attempted to extend the PIGLOG model of consumer preferences to embody more robust structures. For example, Banks, Blundell and Lewbel (1997) generalize PIGLOG preferences by introducing a term that is quadratic in the logarithm of real expenditure into Deaton and Muellbauer's (1980) Almost Ideal Demand System (AIDS) model. They show that for exactly aggregable, rank-three demands, the resulting demand system is quadratic in the logarithm of real expenditure. This Quadratic AIDS (QUAIDS) model allows for more general income and price effects than the AIDS.

[1] Initial efforts to include fish in the model were waylaid given limited availability of information needed to construct a supply-disposition table for fish.

Lewbel's (2003) rational rank-four AIDS (RIADS) model is a further generalization of PIGLOG preferences. In particular, Lewbel (2003) showed that utility derived, budget share based demands can be expressed as a general polynomial of deflated expenditure. In addition, the RAIDS model is a rank for demand system that nests the QUAIDS and AIDS models as special cases that can be tested with linear restrictions on estimated parameters. As such, one would be able to test the rank of the demand system, as supported by the data. The ability to undertake demand system rank tests will further add to economists understanding of the structure of consumer preferences. However, one limitation of Lewbel's RAIDS model is that is not closed under unit scaling, which means that the price elasticities are not independent of the units in which they are measured. This significantly limits the utility of the RAIDS model from an empirical perspective.

At the same time, Piggott's (2003) Nested PIGLOG model not only reflects the AIDS and QUAIDS models, other generalizations of PIGLOG preference structures. An advantage of the nested PIGLOG model is that specific demand models that NPIGLOG embodies can be differentiated by restricting estimable parameters of the model. This means one can statistically test whether the data are consistent with the AIS model, the QUAIDS model, or some other specific functional form embodies in the next PIGLOG structure. (Note that the nested PIGLOG model contains 14 specific functional forms within its general function.) It is noted, however, that the structure if Piggott's NPIGLOG model makes it very challenging with which to work, and can lead to estimation difficulties and failure of estimation algorithms to converge. Indeed, this study set out to use Piggott's NPIGLOG model, but significant computational difficulties led to using the QUAIDS model instead.

Recent work undertaking analysis of retail demand for beef (or meats generally) has emphasized use of contemporary consumer-science and individual level choice models (e.g. Grunert 1997; Bredahl et al. 1998; Verbeke and Viaene 1999; Lusk et al. 2001; Umberger et al. 2002; Bernus et al. 2003; Killinger et al. 2004; Sitz et al. 2005; Bruns et al. 2005; Verbeke et al. 2005; Cox et al. 2006; Krystallis et al. 2007). While useful in understanding acceptance of new products and product-market positioning issues, such analysis does not inform the broader issue of trends in beef demand, how the demand for beef changes overtime and the market-level responsiveness of demand for beef to changes in prices, income and other factors. In this respect, demand analysts have undertaken to estimate beef demand models using time-series data and single equation models or demand systems.

While a number of studies have been published examining demand for beef in the U.S., few studies have been published in Canada. Indeed, much of the previous literature for Canada is somewhat dated (Curtin et al. 1987; Coleman and Meilke 1988; Chen and Veeman 1991; Reynolds and Goddard 1991; Moschini and Moro 1993; Green et al. 1995; Eales 1996; Cranfield and Goddard 1999), or uses cross-section data that does not allow one to track changes in beef demand in response to exogenous events (Lambert et al. 2006). While the general conclusion of this research is that beef demand is inelastic with respect to its own price, the cross-price effects (which measure the nature and strength of the relationship between beef and related goods), has less generalizable results. What is more, the impact of non-economic factors on beef demand has received little attention in Canada.

Indeed, the role of advertising, media coverage and exogenous events on demand for beef has received considerable attention in the U.S. and other countries. Both branded and generic advertising and appear to have a positive impact on demand for beef in the U.S. (e.g. Jensen and Schroeter 1992; Brooker et al. 1994; Brester and Schroeder 1995; Kinnucan et al 1997). Moreover, media reporting of exogenous shocks (such as BSE or food safety recalls) and other potential drivers of demand (such as health information) have been found to affect beef demand in the U.S. (Kinnucan et al 1997; Piggott and Marsh 2004; Marsh et al. 2004) and Europe (Verbeke and Ward 2001). Such effects are apt to play a role in shaping consumer tastes and preferences, and hence the elasticity of demand; the absence of research related to these issues in Canada point to a significant research gap in relation to beef demand in Canada.

Empirical Model

In order to facilitate estimation of a meat demand system for Canada, demand for beef, pork and chicken is assumed to be weakly separable from all other goods. This has the advantage of reducing the number of goods to consider in the demand system, thus reducing the number of parameters to estimate, and reducing the potential for multicollinearity (which might arise when the prices of many goods are included). Invoking weak separability means that the consumer's problem can be broken into two stages. In the first stage, total expenditure is allocated to the commodity group of interest based on the price for that commodity group, the price of other goods and total disposable income. In the second stage, expenditure on the commodity group is then allocated to each good in that group based on the prices of goods in that group and group expenditure.

First stage model

One consequence of assuming weak separability is that the estimated second stage elasticities of demand for each good are conditioned on group expenditure allocated at the first stage. To uncondition these, one must estimate a first stage budget allocation equation for the group. For this purpose, the following double-log equation was estimated:

$$\begin{aligned} ln(EXP_{it}) = a_i + \sum_k a_{ik} QD_{kt} + a_{iT} T + a_{iBSE1} BSEDV1 + \\ a_{iBSE2} BSEDV2 + \sum_{j=1}^{n} b_{ij} \times ln(P_{jt}) + c_i \times ln(Y_t) + \epsilon_{it} \end{aligned} \quad (1)$$

Where QD_{kt} is a dummy variable for the kth quarter in period t, T is a time trend, $BSEDV1$ and $BSEDV2$ are, respectively, dummy variables for Q3 and Q4 2003 (the two quarters immediately following the discovery of BSE infected cattle in Canada), $ln(EXP_{it})$ is the natural log of per capita expenditure on the ith group, $ln(P_{it})$ is the natural log of the price of ith aggregate good in the first stage allocation equation, $ln(Y_t)$ is the natural per capita disposable income, a_i, a_{ik}, a_{iT}, a_{iBSE1}, a_iBSE2, b_{ij} and c_i are parameters to be estimated, and ϵ_it is an error term that is assumed to be distributed as a Normal distribution with mean zero and variance σ^2. Since a double-log functional form is assumed, the own-price elasticity of demand is simply $b_{ii} - 1$, the cross-price elasticities are b_{ij} (for all $i \neq j$), and the income elasticity is c_i.

To address potential endogeneity of meat price in the first stage expenditure allocation model, equation (1) was estimated with an instrumental variable estimator. After experimentation with various possible instruments, aggregate production of beef, pork and chicken (lagged one quarter) was used as the instrument for meat price, while a constant, time trend, $BSEDV1$, $BSEDV2$, dummy variables for quarters 1, 2 and 4, the log of CPI and the log of personal disposable income were included as other instruments.

Second stage model

Initial efforts to estimate Piggott's Nested-PIGLOG model encountered convergence issues that could not be overcome. As such, the Quadratic Almost Ideal Demand System (QUAIDS), a Rank-3 flexible functional form, was estimated in its place. The QUAIDS model is advantageous as it nests the Non-linear Almost Ideal Demand System and, given its flexible form, the QUAIDS embodies very flexible price and income effects. Banks, Blundell and Lewbel (1997) developed the Quadratic AIDS (QUAIDS) model to allow for Engel curves that are potentially non-linear in the log of expenditure. This is done by considering the preference structure needed to obtain a share based demand system that is linear in the log of real expenditure and a general function of real expenditure. By assuming the demands are rank three, exactly aggregable, and derived from utility maximization, they show that the resulting demand system appears as the AIDS model plus a term that is quadratic in the log of real expenditure:

$$w_{it} = \alpha_i + \sum_j \beta_{ij} ln(p_{jt}) + \beta_i ln\left(\frac{y_t}{P_t^*}\right) + \lambda_i \left(\prod_j p_{jt}^{\beta_j}\right)^{-1} ln\left(\frac{y_t}{P_t^*}\right)^2 \quad (2)$$

Where $ln(P_t^*) = \alpha_0 + \sum_i \alpha_i ln(p_{it}) + 0.5 \sum_i \sum_j \beta_{ij} ln(p_{it}) ln(p_{jt})$ is the Translog price index and α_i, β_{ij}, β_i and λ_i are unknown parameters. Adding-up is imposed with the following restrictions $\sum_i \alpha_i = 1$, $\sum_i \beta_i = 0$, $\sum_j \beta_{ij} = 0$ for all i, $\sum_i \lambda_i = 0$; symmetry requires $\beta_{ij} = \beta_{ji}$, while homogeneity requires $\sum_j \beta_{ij} = 0$ for all i . To achieve the degree of generality embodied by QUAIDS, $(n+6)(n-1)/2$ parameters are estimated. Note that $\alpha_0 = 0$ by assumption.

Without further restrictions, predicted budget shares for the QUAIDS can stray outside of the unit simplex an effect that may be exacerbated at extreme expenditure levels given the inclusion of the quadratic term in this demand system. However, the quadratic term does allow for a more general demand response than the AIDS model. Several other points deserve mention. QUAIDS only has local monotonicity and curvature properties. Finally, when $\lambda_i = 0$ for all i, QUAIDS collapses to Deaton and Muellbauer's AIDS model.

The potential impact of trending consumption, seasonality in meat demand, the 2003 BSE event, marketing investment by producers and demographic change in meat demand was accounted for by translating the intercept in each equation (and hence the α_i values in $ln(P_t^*)$). Specifically, α_i was replaced with the following:

$$\begin{aligned} \alpha_i = \alpha_{i0} + \alpha_{it} t + \sum_k \alpha_{ik} QD_{kt} + \\ \alpha_{iBSE1} BSEDV1_t + \alpha_{iBSE2} BSEDV2_t + \alpha_{iMRKT} f(MRKT) + \alpha_{iDEMO} DEMO_t \end{aligned} \tag{3}$$

Where α_{i0}, α_{it}, α_{ik}, α_{iBSE1}, α_{iBSE2}, α_{iMRKT}, and α_{iDEMO} are parameters to be estimated, t, QD_{kt}, $BSEDV1_t$ and $BSEDV2_t$ were defined previosuly, and $DEMO_t$ is a demographic variable (discussed later).

Once estimated, the conditional price elasticities can be calculated by applying the following:

$$\tilde{\eta}_{ij} = \frac{\partial w_{it}}{\partial ln(p_{it})} \frac{1}{w_{it}} - \delta_{ij}$$

while the condition expenditure elasticity is calculated using:

$$\tilde{\eta}_i = \frac{\partial w_{it}}{\partial ln(y_t)} + 1$$

These conditional elasticities are then converted into unconditional elasticities using the formulae found in Fan et al 1995. Note that since the beef marketing investment variable only appears in the second stage, and following the analytical results in Kinnucan and Myrland (2008), the beef marketing elasticities do not need to be unconditioned.

Given the cross-equation restrictions and non-linear structure of the models, a systems estimator is required. Given the structure of the second stage model, concerns exist regarding endogenity or prices and meat expenditure. To address this the Generalize Methods of Moments (GMM) estimator, with a first order moving average lag structure on the errors, was used for estimation. This study follows Eales (1996) in the choice of instruments; in particular, instruments included: the CPI for fuel (CANSIM series number V41691066), the CPI for electricity (CANSIM series number V41691063), a composite index of 10 leading economic indicators (CANSIM series number V7687), the average return on three month treasury bills (CANSIM series number V122484), the Canada-US dollar exchange rate (CANSIM series number V81719).

Additional instruments used during GMM estimation (and are defined later if not already defined): personal disposable income, the All-item CPI, commercial production of beef in Canada, commercial production of pork in Canada, commercial production of chicken in Canada, a constant, time trend, $BSEDV1$, $BSEDV2$, dummy variables for quarters 1, 2 and 4, and the natural log of check-off funds invested in beef marketing in Canada. Because addin-up was imposed, equation (2) is a singular system and so the last equation is dropped during estimation (otherwise the model would be singular and one could not estimate)

Data

Estimation of any demand system requires information on prices, quantities (or budget shares) and expenditure (or income) for the goods under consideration. For this study, the considered goods are beef, pork and chicken. The choice of whether one models the demand system on an annual, quarterly or monthly basis is driven by the context (e.g. is seasonability important) and data availability. Given the potential for seasonality in meat demand, the demand system in equation (2) was estimated using quarterly data. While Statistics Canada and Agriculture Canada report much of the required information, quantities are only available on an annual basis.

As such, quarterly per capita disappearance measures for beef, pork and chicken were calculated using q purpose built supply-disposition tables developed for this study (these tables are available from the author upon request). These disappearance measures were measured in retail product weight. Moreover, since these are disappearance measures, they reflect not just actual consumption, but also food waste. Per capita disappearance was calculated as total disappearance divided by Canada's population (CANSIM series number V1)

While Statistics Canada reports CPI measures for beef, pork and chicken, these are not price levels, but a price index for a corresponding composite good. As such, the price for each meat was calculated as a weighted average of prices for different types of retail products corresponding to that meat category, with weights calculated to reflect the importance of those retail products in the consumer's overall budget (the latter follows Eales 1996). The prices of beef was a weighted average of the retail product price of: round steak (CANSIM series number V735165); sirloin (CANSIM series number V735176); prime rib (CANSIM series number V735187); blade roast (CANSIM series number V735198); stewing beef (CANSIM series number V735209); and ground beef (CANSIM series number V735220). The price of pork was the weight average of: bacon (CANSIM series number V735166); and pork chops (CANSIM series number V735221). The retail price of chicken (CANSIM series number V735223) was used for the price of chicken. The corresponding weights were calculated as the equivalent retail product's budget share from Statistics Canada's 2001 *Food Expenditure in Canada* (shown in Table 1 for beef and pork). For each meat in Table 1, the respective shares were normalized to sum to one.

Table 1. Weights used in calculating beef and pork prices

Retail product price	FOODEX Product	FOODEX Share
	Beef	
Round steak	Hip cuts	0.2949
Sirloin	Loin cuts	0.1249
Prime rib	Rib cuts	0.1211
Blade steak	Chuck cuts	0.0820
Stewing beef	Stewing beef	0.0351
Ground beef	Ground beef	0.3593
	Pork	
Bacon	Bacon	0.1054
Pork chop	Loin cuts	0.2909

Per capita expenditure on each meat was calculated as the product of the meat's price and per capital disappearance. These expenditures were then summed to obtain total per capita meat expenditure. In the first stage model, per capita meat expenditure was used as the dependent variable. A share weighted average of the log of meat prices (i.e. Stone's price index) was used as the log of the price of meats and the log of the All-Item CPI (CANSIM series number V41690973) was used as the price for other goods. Lastly, per capita disposable income was included and calculated as total disposable income (CANSIM series number V499334) divided by population.

In the second stage model, conditional budget shares for each meat were calculated as per capita expenditure on that meat divided by total per capita meat expenditure. Given the meat prices calculated here were highly correlated with corresponding CPIs for beef, pork and chicken, and to enable others to replicate this study, the natural log of the CPI for beef (CANSIM series number V41690978), pork (CANSIM series number V41690979), and chicken (CANSIM series number V41690982) were used as prices in the second stage model. Investment of Canadian cattle producer check-off funds in domestic marketing activities was also included. This marketing spend series was drawn from Cranfield (2010) and updated to 2010.[2] Table 2 shows the means and standard deviations of the variables used in the first stage model and the QUAIDS model.

[2]Initial estimation attempted to included the changing demographic profile of Canadians (captured by including the percent of the male population between 15 and 49 years of age). However, since demographic variables were highly correlated the time trend, their explanatory power was weak and were excluded.

Table 2. Means and standard deviations of the variables

	Mean	Std. dev.
First stage model		
Per capita eat expenditure	141.50	12.81
Meat price	8.04	0.85
All-item CPI	104.14	8.17
Per capita disposable income	5658.75	831.21
QUAIDS model		
Beef's share	46.50%	2.88%
Pork's share	29.58%	4.67%
Chicken's share	23.91%	2.46%
Beef CPI	100.31	13.14
Pork CPI	100.65	5.73
Chicken CPI	110.99	14.28
Per capita beef marketing investment	0.039	0.017

Results

First-stage Model

Table 3 shows the regression results for the first stage model where natural log of expenditure on meat was regressed on the natural log of the price of meat, the natural log of the price of other goods, the natural log of personal disposable income, a time trend, quarterly dummy variables and dummy variables capturing the quarter in which the BSE crisis began (Q2 2003) and the subsequent quarter (Q3 2003). As mentioned, potential endogeneity of the price of meat led to use of instrumental variable estimation, with aggregate meat production (of beef, pork and chicken) used as instrument.

The estimated model fit the data well ($\bar{R}^2$=0.86) and had overall significance (F-stat=28.98, p-value <0.001). While the intercept, and coefficients on the trend variable and seasonal dummy variables were not significant (at the ten per cent level of better), the coefficient on the dummy variable for one of the BSE dummy variables was significant (t=2.387, p-value=0.017) and positive. The latter indicates that meat expenditure was significantly higher in the quarter after the discovery of BSE affected cattle in Canada in May of 2003. While the coefficients on the price of other goods variable and personal disposable income were not significant, the coefficient on the price of meat was significant (t=2.442, p-value=0.015).

Table 3. Instrumental variable estimation results for the first-stage meat expenditure equation

Variable	Coefficient	t-statistic
C	-0.763	-0.109
T	-0.003	-0.764
BSEDV1	0.007	0.195
BSEDV2	0.086**	2.387
Q1	0.016	0.415
Q2	0.005	0.334
Q4	-0.030	-0.811
LPMEAT	0.760**	2.442
LCPI	-0.428	-0.229
LPDI	0.488	0.642

** - denotes significant at the five per cent level

Given the log of expenditure was regressed on the log of meat price, the own-price elasticity of demand for the meat good equals the coefficient on the own-price variable minus one. Evaluated using the estimate in Table 3, the own-price elasticity of demand for meat in Canada is estimated to equal -0.239, but is not significantly different from zero (t=-0.771, p-value=0.441). Nonetheless, the value of this elasticity indicates that a ten per cent increase in the price of the meat aggregate would lead to a 2.39 per cent increase in demand for meat.

For comparative purposes, note that Okrent and Alston (2011) report a first stage own-price demand elasticity for the United States from two different models. When using the NBR model with annual data from 1960-2009, the estimate the own-price elasticity of demand for meat to equal -0.4. When using a first-difference linear-approximate AIDS model with monthly data over the period 1998-2009, their point estimate for the meat demand elasticity equalled -0.12. While the numerical estimates are different between Okrent and Alston and the present study, they are all inelastic and that report here falls between those reported by Okrent and Alston, even though the data have different frequency, are from a different country and with a different model; that the estimates are so similar is comforting.

The cross-price elasticity of demand between meat and other goods is -0.428 (i.e. the coefficient on the price of other goods), indicating a complementary relationship (but note that this coefficient is not significantly different from zero). The income elasticity of demand (which is simply the coefficient on the personal disposable income variable) is positive and less than one, indicating meat is normal good. However, the estimate of the income elasticity of demand for meat is not significantly different from zero.

Again, Okrent and Alston (2011) report the elasticity of meat demand of 0.64 using annual data from 1960 to 2009, but 0.02 when using monthly data from 1998 to 2009. As the meat demand elasticity with respect to expenditure in this study is 0.488, the results reported here are in the "ball-park" of those reported recently for the United States.

Second-stage model

Table 4 shows the GMM estimates of the QUAIDS coefficients, their t-statistics and regression summary statistics. Note that the estimated model satisfies the monotonicity and concavity property at every point in the data; the fitted budget shares were all greater than zero, and the eigenvalues of the Cholesky decomposition of the matrix of compensated price effects were all less than or equal to zero (when evaluated at each point in the data).

Table 4. GMM estimates of the QUAIDS parameters

	Beef	Pork
α_{i0}	-0.633	0.295
	(-1.538)	(0.621)
α_{i1}	-0.006	0.015*
	(-0.799)	(1.769)
α_{i2}	0.007	-0.001
	(0.700)	(-0.144)
α_{i4}	−0.013*	0.025***
	(-1.609)	(3.488)
α_{iT}	0.001**	−0.002***
	(2.018)	(-2.763)
α_{iBSE1}	0.034*	−0.036*
	(1.615)	(-1.732)
α_{iBSE2}	0.021	-0.007
	(0.426)	(-0.131)
α_{iBMRKT}	0.006	−0.009*
	(1.146)	(-1.720)
α_{iBeef}	-0.258	
	(-1.262)	
α_{iPork}	-0.043	0.077
	(-0.305)	(0.632)
β_i	0.385***	-0.019
	(3.548)	(-0.221)
λ_i	−0.044*	0.007
	(-1.913)	(0.329)
$\bar{R}^2$	0.820	0.918
DW	2.085	2.049

t-stats in parentheses
*** - significant at one per cent
** - significant at five per cent
* - significant at ten per cent

The estimated equations fit the data well; the $\bar{R}^2$ values indicate that the estimated beef and pork equations explain 82 and 92 per cent of the variation in the respective budget shares. As well, the Durbin-Watson statistics suggest that regression errors do not suffer from autocorrelation. As indicated, a number of the estimated coefficients are significant at the one, five or ten per cent confidence level. As these coefficients are not the main focus of this study (the resulting elasticities are the main focus), their signs and significance will not be discussed in detail.

It is important to note that the estimated coefficients on the deflated log of income (β_i) and square of the deflated log of income (λ_i) in the beef equation are significantly difference from zero. Moreover, the test of the joint null hypothesis that $\lambda_i = 0$ for all i was rejected at the five per cent level (p-value=0.03). Given this, we can reject the null hypothesis that the AIDS model is preferred over the QUAIDS model, and the estimated QUAIDS results are used for the subsequent analysis.

Conditional Elasticities

Table 5 shows summary statistics for the conditional uncompensated price elasticities, the conditional expenditure elasticities and adverting elasticities. (The tables of elasticities report the mean and standard error of these elasticities; point estimates of the elasticities at each point in the data are available upon request.) All own-price elasticities are negative (as expected) and statistically significant, and all own-price elasticities are inelastic. The latter result is somewhat expected as most previously estimated meat demand elasticities have reported inelastic own-price effects. Important for this study is that beef's conditional own-price elasticity is -0.83. The conditional uncompensated cross-price elasticities suggest a gross-complement relationship between beef and pork and beef and chicken, but gross-substitute between pork and chicken.

Table 5. Conditional, uncompensated price elasticities, expenditure elasticities and beef marketing elasticities

	Beef price	Pork price	Chicken price	Meat expenditure	Beef marketing
Beef	-0.829^{***}	-0.155	-0.133	1.117^{***}	0.017
	(-3.270)	(-0.817)	(-1.243)	(4.310)	(1.036)
Pork	-0.244	-0.755^{*}	-0.108	1.106^{**}	-0.032
	(-0.488)	(-1.931)	(-0.505)	(2.257)	(-1.504)
Chicken	-0.040	0.007	-0.609^{***}	0.642	0.006
	(-0.113)	(0.020)	(-3.601)	(1.382)	(0.258)

t-stats in parentheses
*** - significant at one per cent
** - significant at five per cent

Meat expenditure elasticities are positive and significant for beef and pork, but positive and insignificant for chicken. Further, beef and pork are luxury goods with respect to meat expenditure, while chicken is a normal good. Note, however, that these are conditional expenditure elasticities and they will be transformed into unconditional estimates in the subsequent section.

The elasticity of demand for each meat with respect to beef marketing investment is positive for beef and chicken, but negative for pork, but none of the estimates are significantly different from zero at ten per cent. For comparison purposes, note that Cranfield (2010) estimated an elasticity of beef demand with respect to beef marketing of 0.023, while the present study estimates this value at 0.017. While the two estimates are different, they are not drastically so. Nonetheless, as this study only included beef marketing investment, it remains to be determined how pork and chicken marketing investment (both generic and branded) influence these results; this is left for further research.

To provide more insight into how the conditional own-price elasticity of demand for beef has changed overtime, Figure 1 plots the point estimates of this elasticity in each period under study and the 95 per cent confidence bounds. As evident from the figure, this elasticity has not changed appreciably over the timeframe considered; its minimum value was -0.86 and its maximum as -0.79. However, it is important to remember that this is a conditional elasticity estimate. As such, these estimates will be unconditioned following the approach outlined above.

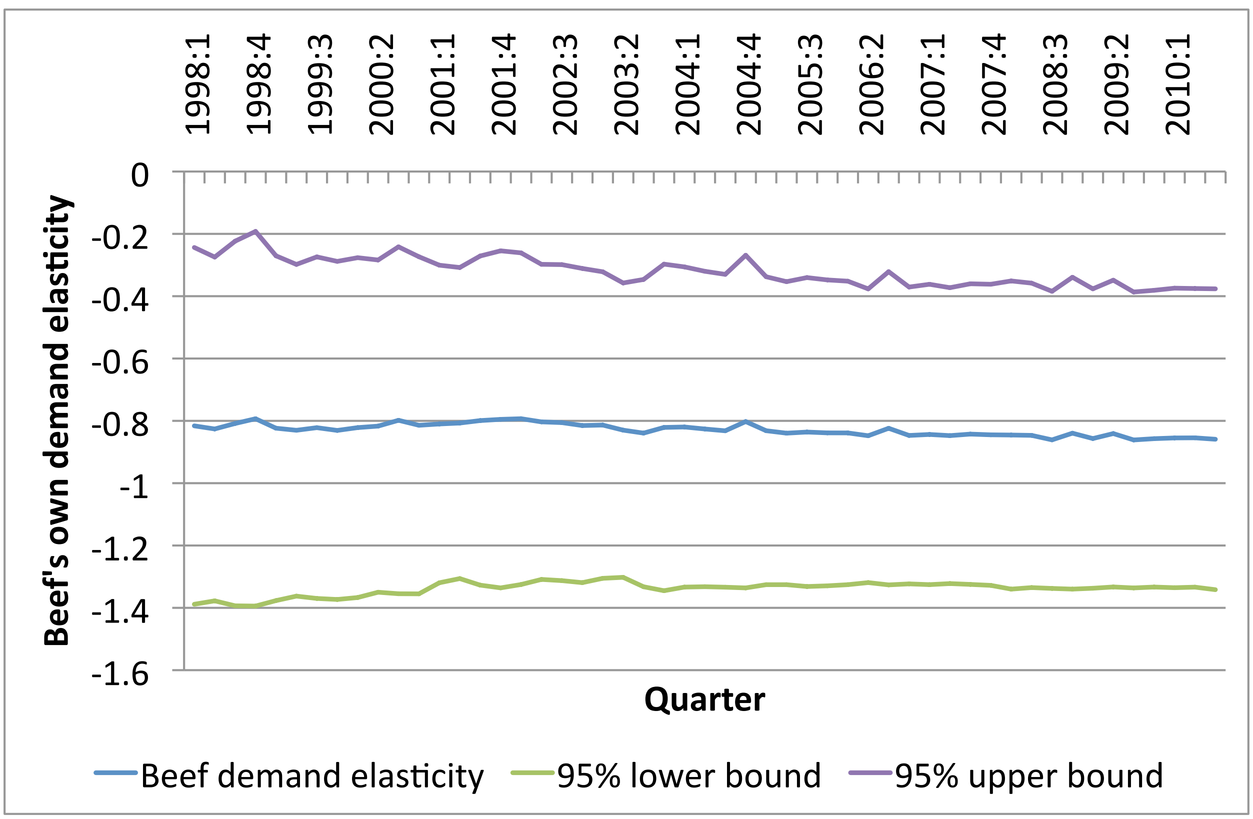

Figure 1. Conditional, uncompensated own-price elasticity for beef, 1998:1 to 2010:3.

Table 6 shows the conditional compensated price elasticities (calculated using the Slutsky equation). All conditional, compensated own-price effects are negative (reflecting the law of demand), while all cross-price effects are positive and indicate a net substitute relationship between these meats (conditional on the first stage). However, only the own-price elasticities for beef and chicken are significantly different from zero. Nonetheless, as expected, the conditional, compensated own-price elasticities are smaller than their uncompensated counterparts.

Table 6. Conditional, compensated price elasticities

	Beef price	Pork price	Chicken price
Beef	-0.310^{*}	0.175	0.135
	(-1.789)	(0.847)	(1.489)
Pork	0.271	-0.428	0.157
	(0.847)	(-0.991)	(0.897)
Chicken	0.259	0.196	-0.455^{**}
	(1.489)	(0.897)	(-2.512)

t-stats in parentheses
** - significant at five per cent
* - significant at ten per cent

Unconditional Elasticities

Table 7 shows the unconditional, uncompensated price elasticities of demand, as well as the unconditional expenditure elasticities. All uncompensated own-price elasticities are negative, as expected, and two (beef and chicken) are significant at the ten per cent level or better. Regardless of level of significance beef demand is most inelastic, followed by chicken demand and then pork demand. All cross-price elasticities of demand are positive, indicating a gross-substitute relationship between beef, pork and chicken, but not significant.

All unconditional expenditure elasticities are greater than zero and less than one, suggesting that beef, pork and chicken are normal goods with respect to personal disposable income. Beef and pork demand have income elasticities of around 0.54, while chicken is more income inelastic. Lastly, the unconditional expenditure elasticities are significant for beef and pork. It is noted that Canadian beef demand is more income inelastic than U.S. beef demand. Specifically, Tonsor et al. (2011) report an income elasticity of demand for beef of 0.91. Just why these two countries would have different income elasticities of demand for beef is an interesting question. Differences can stem from differences in methods used (i.e. demand system and estimator), but also could relate to fundamental differences in preferences and possibly to differences in the distribution of income that shifts beef closer to the limit between a normal and luxury good in the U.S. than in Canada.

Figure 2 plots the point estimates of the unconditional uncompensated beef demand elasticity in each period under study and the 95 per cent confidence bounds. Several points stand out. First, the unconditional beef demand elasticity is negative and significant in all observations. Second, the point estimates change little over time, ranging from -0.4 to -0.46. However, there appears to be a noticeable change in the value of this elasticity in the middle of the sample; indeed, the unconditional beef demand elasticity became noticeably more inelastic immediately after quarter 3 2003 (i.e. after the BSE crisis), but showed little variation or noticeable change thereafter.

Table 7. Unconditional, uncompensated price and expenditure elasticities

	Beef price	Pork price	Chicken price	Meat expenditure
Beef	-0.434^{**}	0.096	0.070	0.545^{***}
	(-2.305)	(0.477)	(0.778)	(4.310)
Pork	0.148	-0.507	0.093	0.540^{**}
	(0.423)	(-1.215)	(0.531)	(2.257)
Chicken	0.187	0.150	-0.492^{***}	0.313
	(0.920)	(0.686)	(-2.865)	(1.382)

t-stats in parentheses
*** - significant at one per cent
** - significant at five per cent
* - significant at ten per cent

Unconditional compensated price elasticities are shown in Table 8. As expected, the compensated own-price elasticities have negative sign (reflecting the law of demand). Moreover, all compensated own-price elasticities are inelastic, and those for beef and chicken are significant at the ten per cent level or better. Beef is the most inelastic meat, followed by chicken and then pork. Cross-price elasticities, while not significantly different from zero, all reflect a net-substitute relationship between meats.

While Tonsor et al. (2011) did not report uncompensated price elasticities, they did report (unconditional) compensated price elasticities. Interestingly, their estimate of the compensated own-price effect for beef is -0.419, while that reported here is -0.428. While different demand systems were estimated, and the timeframe was different, similarities in these two countries compensated demand elasticities provides some triangulation that lends confidence in these results. Moreover, it may come as no surprise that these elasticities are similar given the integration of Canadian and U.S. beef markets. What is also interesting, and perhaps reflects similarities in underling preferences, is that Tonsor et al. (2011) report the compensated cross-price elasticities of demand between meats in the U.S. to be insignificant, just as reported here.

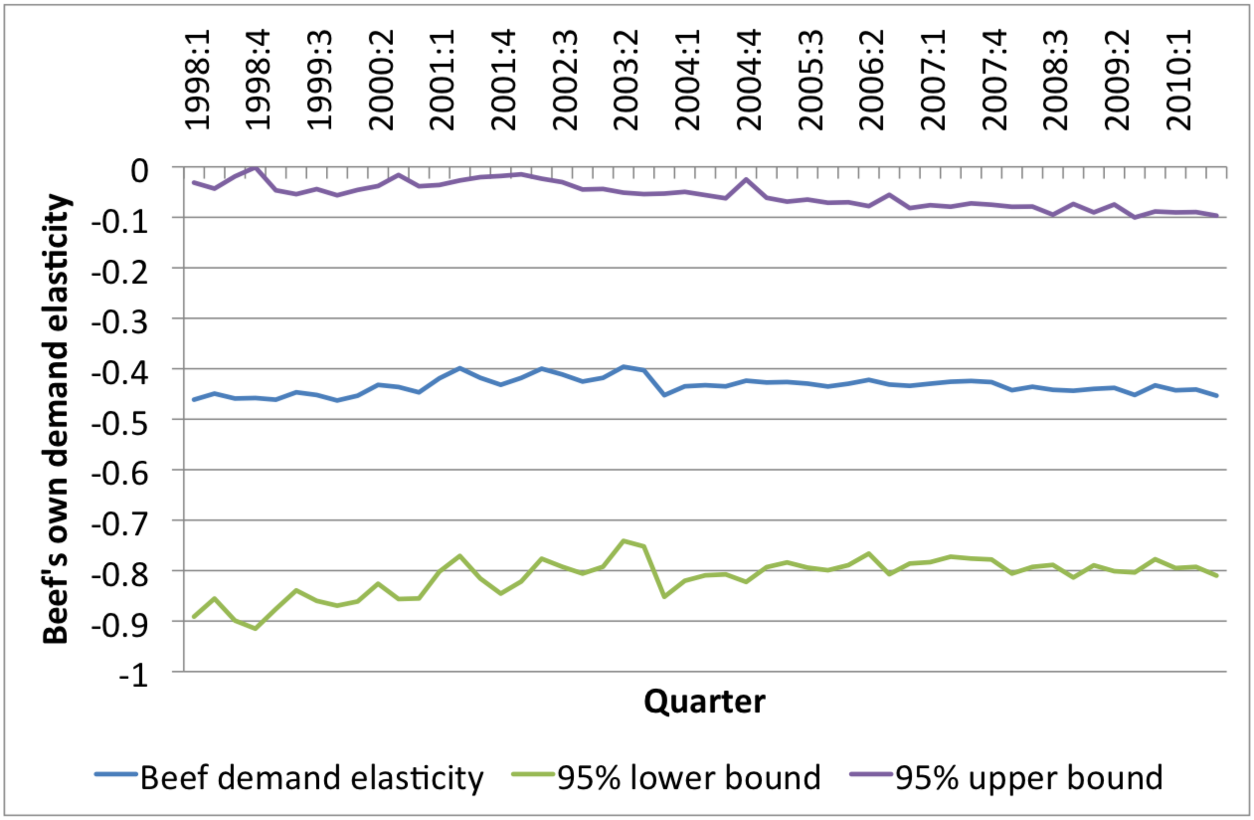

Figure 2. Unconditional, uncompensated own-price elasticity for beef, 1998:1 to 2010:3.

Table 8. Unconditional, compensated price elasticities

	Beef price	Pork price	Chicken price
Beef	-0.428^{**}	0.100	0.074
	(-2.281)	(0.497)	(0.815)
Pork	0.154	-0.502	0.097
	(0.443)	(-1.203)	(0.550)
Chicken	0.191	0.153	-0.490^{***}
	(0.945)	(0.697)	(-2.848)

t-stats in parentheses

*** - significant at one per cent

** - significant at five per cent

Conclusion

The purpose of this study was to provide updated beef demand elasticity estimates for Canada. To this end, a Quadratic, Almost Ideal Demand System was estimated for beef, pork and chicken in Canada using quarterly data from 1998 to 2010. Demand for these three meats was assumed to be weakly separable from all other goods, thus necessitating the estimation of a first-stage model for the two-stage budgeting process implied by weak separability. Results for the first stage model indicate demand for these three meats in Canada is inelastic, with an own-price elasticity of -0.24.

The estimated second-stage QUAIDS model was consistent with well-behaved preferences. Regardless of whether one used conditional or unconditional demand elasticities, demand for beef in Canada was inelastic during the period under study. The conditional, uncompensated own-price elasticity of demand was -0.83. After conditioning on the level of meat expenditure in the first stage, the unconditional, uncompensated elasticity of demand for beef was -0.43, a value that is extremely close to a recent estimate of beef demand in the United States (see Tonsor et al 2011). Moreover, the unconditional, uncompensated own-price elasticity of demand for beef in Canada appeared to become more inelastic prior to discovery of BSE in Canada (see Figure 2), but that trend abated since then. While demand looks as those it may have become slightly less inelastic (again, see Figure 2), the change is subtle.

While the estimated model provides new, and arguably more flexible, meat demand elasticities for Canada, further research is needed. The present model only included beef marketing investment by cattle producers. As such, one area of further research is to include investment in marketing (i.e., advertising and promotion) by not only hog and chicken producers, but also by private firms selling the result food products. An additional area of future research relates to incorporation of quantity pre-commitments and estimation using Piggott's NPIGLOG model. Computational difficulties encountered during this study prevented use of NPIGLOG, as such, future efforts need to focus on the discovering the structure of NPIGLOG that prevented convergence of the estimator and developing strategies to overcome these limitations. Lastly, the model included here only considered a subset of meats from land based animals. Incorporating fish into the model, and indeed other sources of animal and non-animal protein, will further enrich the analysis and shed deeper insight into the nature of Canadian consumer demand for beef.

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