Evaluating the Economic Benefits From the Canadian Beef Check-Off

Prepared by James Rude and Ellen Goddard
With the assistance of Violet Muringai
July 19, 2016

Executive Summary

Beef producers across Canada pay a mandatory check-off levy to their respective provinces on each animal marketed. The national portion of this levy is $1 per head of cattle sold. The levy that is collected on cattle sales throughout Canada funds research and marketing activities for the entire industry. Since 2012 the national check-off has been administered by Canada Beef Inc. when the Canadian Beef Cattle Research, Market Development and Promotion Agency (NCOA) was consolidated with the Beef Information Centre and the Canadian Beef Export Federation. Over the last decade this check-off provided over $120 million to promote the industry through marketing and development. About half way into this time period concerns were raised that the check-off did not provide adequate funding for beef and cattle marketing and research activities. At that time a study was commissioned (Cranfield 2010) to measure the rate of return to producer investments in marketing and research.

The Cranfield study provided a broad picture of the economics of check-offs and returns to the Canadian program. Using international comparisons, Cranfield found that prior research on rates of return for marketing ranged from 1:1 to 24:1; while his own study estimated Benefit-Cost Ratios (BCR), associated with the investment of producer check-off dollars in marketing and research activities, that grew from 7:1 to 11:1, over the period between 2005 and 2008.

This document reports on results which extend and update the earlier evaluation of the impact of check-off-funded marketing and research activities on the economic well-being of Canadian beef cattle producers. The analysis focused on a single core question: *What is the historic producer return to investment in marketing and research activities?*

The analysis in this study uses an updated (to 2014) and re-estimated econometric simulation model that mimics the beef and cattle markets in Canada and the U.S. To be comparable to Cranfield's model this model explicitly accounts for the impact that Canadian cattle-producer investments in beef cattle marketing and research activities have on prices and quantities in these markets. The model enables one to calculate retail and farm-level prices for beef and live cattle, respectively; final consumer demand for beef; production of beef; packer demand for cattle; supply of fed and non-fed cattle; and beef and cattle trade for a baseline situation and a variety of "what-if" scenarios. The baseline situation reflects what actually happened in these markets and is used as the basis of comparison for the "what-if" scenarios. The "what-if" scenarios allow one to determine the retail and farm-level prices and quantities that would result if investments in marketing and research activities were different from the actual levels of investment.

Analysis with this updated model showed that Canadian cattle producers gain net economic benefits from investment in marketing and research activities. Specifically, between 2011 and 2014 the BCR associated with the investment of producer check-off dollars in marketing and research activities grew from 7:1 to 24:1, with an average BCR of 14:1 over this time period. This means that on average from 2011 to 2014, every check-off dollar invested in marketing and research activities earned $14.19 for Canadian cattle producers.

Although in this study no explicit analysis of optimal investment in the various marketing and research activities was undertaken there is no reason to assume that the Cranfield analysis showing that higher investments improve the welfare of Canadian cattle producers is in error. In fact, the similar but slightly higher elasticities associated with the data for the more recent period suggest that even more investment is warranted.

In a number of ways, the results from this study are even more encouraging than those from the earlier study. In the majority of cases results from the regression estimations in this study suggest statistically significant responses in a variety of beef industry variables to the actual investments by the beef industry in marketing/promotion and research (domestic per capita disappearance, exports, slaughter, for example) – better results than those found in Cranfield (which may have been limited by length of data available for analysis). Higher statistical significance suggests narrower confidence intervals and more robust measures of impact of the study. Although there are numerous sophisticated econometric analyses that could be applied to refine the BCR's reported in this study, that the impact is positive for Canadian producers is not in doubt, in fact might be somewhat higher than the earlier estimates. Changes in the level of investment over the period now included in the analysis possibly provided richer data allowing us to estimate regression parameters more accurately.

Table of Contents

1. Introduction 4

2. Background Information 5

3. Overview of the Economic Model 7

4. Check-Off Revenue & Marketing and Research Investment 10

5. Analysis of the Economic Benefits from the Check-Off 11

6. Summary and Conclusions 17

7. Appendix 1: Econometric Estimates & Simulation 19

8. Appendix 2: Data Sources 35

1. Introduction

The Canadian Beef Cattle Research, Market Development and Promotion Agency — the national check-off (NCOA) agency — was established in 2002. The agency is involved in national beef research programs (with further investment from Agriculture and Agri-food Canada (AAFC)), in international marketing of Canadian beef and in domestic promotion and marketing of beef. Since 2002 the beef industry has faced significant challenges: border closures and additional marketing transactions costs associated with the discovery of BSE-infected bovine animals beginning in 2003, further thickening of U.S. borders to live animal trade as a result of U.S. mandatory Country of Origin Labelling, surging feed grain prices, and a higher valued Canadian dollar. Accounting for the challenging international market environment, Cranfield (2010) analyzed the economic impact on the wellbeing of Canadian cattle producers from the NCOA's investments in market promotion and production research.

Cranfield's (2010) analysis focused on three core questions:

- What is the historic producer return to investment in marketing and research?
- How can the allocation of check-off funds be optimized across marketing and research?
- What impact does optimizing check-off fund investment in marketing and research activities have on the economic well-being of Canadian cattle producers?

The results of the Cranfield study showed that Canadian cattle producers gained net economic benefits from these investments in marketing and research activities. Between 2005 and 2008 the benefit to cost ratio associated with the investment of producer check-off dollars in marketing and research activities grew from 7:1 to 11:1, with an average benefit cost ratio of 9:1.

The purpose of this study is to update these results. This update is necessary because of changes to the check-off program and to the methods by which market promotion and production research are funded. These changes include the implementation of the AAFC Science Cluster program and merging of the *Beef Information Centre* and the *Canada Beef Export Federation* into a single agency - Canada Beef Inc.

This report provides an abbreviated version of the report provided by Cranfield (2010). We will only address the first of Cranfield's three core questions or the historic producer return to investment from marketing and research activities. As with the Cranfield report, this study employs an econometric simulation model to undertake the analysis. The model is first used to create a baseline scenario which reflects historic market conditions in the North American (including the Rest of the World) cattle and beef markets. A counterfactual scenario is then developed which considers the impacts of eliminating market promotion and production research expenditures on market prices and quantities produced, consumed and traded at the live cattle and processed beef levels of the market. Given this information it is possible to calculate various returns on investment in terms of the ratio of net returns to producers relative to the investment cost of the programs (Benefit Cost Ratios - BCR). Unlike the original study we do not attempt to determine the optimal level of investment for market promotion activities or consider the potential impact of refund requests by Alberta cattle producers.

First we provide a background on the context and institutional arrangements for producer check-offs in the Canadian beef sector, and a short review of prior empirical estimates of cost benefit ratios for investments in beef market promotion and production research. This information sets the context to assess the BCR developed in this study and the prior estimates from the Cranfield (2010) study. In the next section we provide an overview of the economic model employed in this study. Next we provide a discussion about the check-off revenue and investments in marketing and research. Finally, we provide an analysis of the economic benefits of the check-off investments.

2. Background Information

Beef producers in Canada pay both provincial and national levies or check-offs. The provincial check-offs vary, with the provincial component of the total check-off being allocated to support the respective provincial association's activities. The 'national check-off 'portion is a mandatory levy of $1 per head. The national check-off is administered by the Canadian Beef Cattle Research, Market Development and Promotion Agency (NCO) established under the Farm Products Council of Canada. Table 2.1 provides a summary of the check-off value by province and the allocation of the dollars to the various beef organizations including Canada Beef Inc. (CBI) and the Beef Cattle Research Council (BCRC).

Table 2.1: National and provincial levy rates for Canada

Province	Provincial levy per transaction	Allocated to province	Allocated to National Check-off	Allocation
British Columbia	$3.00	$2.00 (refundable)	$1.00	90% to CBI; 10% to BCRC
Alberta	$3.00	$2.00 (refundable)	$1.00	80% to CBI; 20% to BCRC
Saskatchewan	$3.00	$2.00 (refundable)	$1.00	70% to CBI; 30% to BCRC
Manitoba	$4.00	$3.00 (refundable)	$1.00	85.5% to CBI; 7% to BCRC; 7.5% provincial initiatives
Ontario	$4.00	$3.00 (non-refundable)	$1.00	32.6% to CBI; 17.4% to BCRC; 50% provincial initiatives
Quebec	Range $5.04/calf ↔$13.79/ cull cow		$1.00	3.0% to CBI; 97% provincial initiatives
New Brunswick	$3.00	$2.00 (non-refundable)	$1.00	10% to CBI; 90% provincial initiatives
Nova Scotia	$3.00	$2.00 (non-refundable)	$1.00	2% to CBI; 10% to BCRC; 88% provincial initiatives
PEI	$4.00 at slaughter only	$3.00 (non-refundable)	$1.00	2% to CBI;98% provincial initiatives

Source: Canada's National Beef Strategy at http://beefstrategy.com/producer-check-offs.php

As of 2012 the national check-off provides industry funding for the BCRC and for the CBI. Prior to 2012, funding was provided to the Beef Information Centre (BIC), the Canada Beef Export Federation (CBEF) and the Beef Cattle Research Council (BCRC). The BIC was responsible for marketing activities for Canadian beef in Canada and the U.S. The CBEF was responsible for the promotion of Canadian beef outside Canada and the U.S. In addition to check-off funding the CBEF received money from membership fees and other non-check-off funds. The focus of CBEF activities included local market representation and promotion, Canadian beef branding and strategic market research. The BCRC co-ordinates investment in beef cattle production research. Nationally, the BCRC receives on average 15 cents of every national check-off dollar. This check-off funding is used to leverage additional industry and government funding including the funding provided through Agriculture and Agri-Food Canada's Beef Cattle Industry Science Cluster.

Cranfield (2010) provided a review of empirical outcomes from the economics literature on the BCR for investments in domestic marketing, foreign marketing, and production research. The scope of the review was broad with coverage of beef promotion and research expenditures across several countries, but also a comparison of BCRs across different commodities. Given the existence of the 2010 study a repeat of this literature is not necessary. However, several important findings should be highlighted and repeated from Cranfield's literature review. First, a marginal BCR shows the change in market-level producer benefits arising from a small change in investment in producer-funded activities. A marginal BCR greater than one indicates the last dollar of investment returns more than $1 in benefits. This is a sign of under-investment and the agency should invest more to lower the BCR to closer to one without reducing it below the target of a BCR of unity.

Returns to investment in domestic marketing would range from 1.3:1 to 24:1, but typically are in the 5:1 to 10:1 range. Returns to export promotion investment ranged from 15:1 to 18:1. So Cranfield concluded that returns to investment in domestic marketing activities tend to be smaller than returns to export market promotion (however this an empirical question in different contexts, for different products and in different time periods). Returns to production research were in a much higher range from 26:1 to 57:1. These very high returns imply significant under investment in production research (and this has been regularly identified by researchers such as Alston *et al.* (2000) and Gray and Malla (2007)). So it is possible to make an *a priori* expected ranking of current beef industry BCRs with the highest expected returns for production research, smaller expected returns for export promotion; and even smaller expected returns for domestic market promotion. Cranfield proposed that differences in the return to domestic marketing activities and export marketing activities relate to the diffuse nature of many domestic marketing activities, versus the targeted nature of export marketing activities. However, it could also relate to level of promotional investment in each market.

What Cranfield is able to do is propose a reasonable range for estimated BCRs to be expected to fall into. His results – 7.6:1 for market promotion and 46:1 for production research – fall within reasonable ranges associated with other studies. The question remains whether current results continue to be at the high end of this range.

3. Overview of the Economic Model

An approach similar to Cranfield (2010) is used to measure the change in producer benefits associated with an investment of check-off funds in marketing and research activities. His approach measured producer benefits associated with the actual investment of check-off funds and then asked: “how big would these producer benefits have been, had the check-off funds not been invested?” The difference between actual producer benefits and those estimated to have occurred in the absence of check-off fund investment in marketing and research provides an estimate of the economic impact of the check-off investment.

The merit of this approach is that it measures the impact of expenditures on marketing and production research on the prices producers receive and the quantity of live cattle supplied, demanded and traded, holding all other influences on these variables constant. However, this requires an econometric model that captures the vertical structure of the North American cattle and beef industries while accounting for the actions of cow-calf operators and of feedlots, resulting in levels of cattle slaughter and meat processing, domestic beef consumption and international trade of cattle and beef. This approach allows the researcher to predict prices and quantities in the absence of the check-off program. So the model explicitly accounts for the impact of Canadian cattle producer investment in beef cattle marketing and research activities on prices and quantities across the cattle/beef value chain.

3.1. Broad Overview of the Model & Analysis

The econometric model provides a broad array of information that describes the North American cattle/beef market. The model estimates farm-level and retail prices for live cattle and beef; breeding inventories, the supply of fed and non-feed cattle that are marketed; packer demand for cattle; final consumer demand for beef; and trade in cattle and beef. The model is solved first to create a baseline. The baseline is validated again actual data from recent history. This baseline is then used as the basis of comparison against the different “what-if” scenarios where investments in market promotion and production research are reduced to correspond to a situation where check-off funds are removed.

It is important to take explicit account of BIC, CBEF and BCRC investment in marketing and research activities and to determine the appropriate equations to incorporate these expenditures into the structural model. BIC investment in marketing activities in Canada is included in a retail Canadian demand equation for beef. The expectation is that as marketing activities expand demand will increase, leading to pressures for higher beef prices and ultimately higher cattle prices. The structural model will account for these changes throughout the entire beef cattle sector and trace the effects back to the farm level.

BIC investment in U.S. marketing activities is introduced into a U.S. import demand equation for Canadian beef. Again increased marketing expenditures expand demand putting pressure on retail beef prices and ultimately increasing farm level prices. The approach we used is different from Cranfield (2010) who included these expenditures in a net beef export equation. Net exports equal Canadian exports to the U.S. less Canadian imports of U.S. beef. Estimating net exports is not as clean and straight forward an approach as estimating U.S. import demand for Canadian beef which is likely to be a direct function of BIC (U.S.) expenditures. A model specification that allows for distinct estimation of the U.S. demand for Canadian beef is based on the assumption that Canadian beef is not a perfect substitute for U.S. beef (something easily justified in the context of the U.S. COOL regulations and also due to different industry regulations on specified risk materials that arose from the BSE incidents in Canada). We estimate the U.S import demand function directly.

It is important to recognize that the BIC receives funds from both the check-off levy and other sources (e.g., Legacy funds, National Beef Industry Development Fund, etc.). Section 5.3 explains how check-off expenditures are determined as a share of total BIC expenditures. Total BIC expenditures influence Canadian domestic and US import demand for Canadian beef and therefore total expenditures are included in the regressions for these two endogenous variables. However, when the policy changes are simulated only that part of BIC expenditures associated with the check-off should be changed and the rest of the expenditures (from other sources) should be held constant. This approach is consistent with Cranfield (2010) and the interested reader should consult his paper for a justification for this approach.

CBEF expenditures on marketing activities are to limited off-shore international markets (everywhere except the U.S. and Canada). Again an import demand equation is estimated for the Rest-of-World's (ROW) demand for Canadian beef exports. Cranfield used a net export approach and for the same reasons as in the case of U.S. demand for Canadian beef, we have chosen to alternatively estimate import demand directly. Higher import demand that results from increased promotion should increase trade leading to higher beef and cattle prices increasing producer welfare. It should be noted that the CBEF receives revenues not only from the check-off, but also from other sources. Import demand is a function of CBEF expenditure from all sources, but the policy simulations must account only for changes associated with check-off funds and only these expenditures should be adjusted in this analysis.

BCRC investment in beef cattle research is included in supply equations for fed and non-fed cattle, as well as in equations for carcass weights of slaughter-weight Canadian steers and heifers. The idea here is that investment in beef cattle research should lead to an increase in production efficiencies that lead to increased beef production (through higher carcass weights or increased supply of live cattle, or both). Increased production will increase producer revenues but may also have a minor price depressing effect on cattle prices (given that this is a North American market and Canada has little effect on prices the price impact should be minor).

3.2. Description of the Econometric Simulation Model

A more detailed description of the model, as well as econometric estimation results, is provided in Appendix 1. Formally it is a multi-market partial equilibrium model of the Canadian and U.S. beef cattle industry. A competitive market structure is assumed to apply at all levels of the supply chain. The framework accounts for producer and processor behaviour with respect to live cattle and then links beef production, through a packer, to the final demand of the consumer.

The supply side of the model attempts to account for most stages of cattle production (cow-calf, fed cattle production). The model starts with an equation that explains the inventory of breading cows. This inventory helps to determine available supplies of cull and fed cattle that are sold for slaughter. In each country, the supply of fed cattle is related to past values of the beef cow herd inventory and price variables that affect profitability. Including lagged beef cow inventories in the supply of fed cattle generates a dynamic supply response throughout model. The supply of non-fed cattle in each country is related to the inventory of beef and dairy cows in the current period. The BCRC investment variable is included in both of these supply equations.

The cattle and beef markets are vertically linked with a fixed proportions relationship where the quantity of beef produced is equal to the average carcass weight times the number of animals demanded by packing plants. There are separate packer demands for fed and non-fed cattle. The fed-cattle (slaughter-weight steers and heifers) packer demand is a function of the retail price of beef, the price of fed cattle, and the wage rate in the packing industry. Likewise, non-fed cattle (culled cows and bulls) packer demand is a function of the price of beef, price of slaughter cows, and a wage rate in the packing industry. Multiplying fed and non-fed cattle slaughter by appropriate carcass weights and summing then yields beef production. A separate demand equation for fed-cattle carcass weight is estimated as a function of the ratio of the price of fed cattle to the price of feed and a variable capturing investment in beef cattle research.

Demand at the retail level of each market is estimated as per-capita demand (aggregate quantity or disappearance of beef divided by population) which is function of retail prices for beef, pork and chicken. A BIC advertising variable is included in this demand equation. Per capita demand is then translated into total beef demand with an identity that multiples the respective countries population by its per-capita demand. Import demand in the U.S. is a function of relative Canadian/U.S. beef prices (adjusted for exchange rates), dummy variables for border closures, U.S. income, and BIC (US) promotion expenditure. Import demand for the Rest-of-World is estimated as a function of relative Canadian/Australian beef prices, CBEF promotion expenditures and dummy variables for border closures (related to BSE and to COOL).

The model is closed by a series of market clearing identities for Canada and the U.S. Each beef market clearing identity accounts for a complete supply-disposition. Beef disappearance (demand) is required to equal production plus beginning stocks plus imports minus exports and minus ending stocks. Except where identified above, exogenous variables, such as stocks, are held at historic levels through-out the analysis. There are market clearing identities for fed and non-fed cattle, for each country, which equate the marketed supply (of animals) to packer demand for animals for slaughter plus/minus exports/imports of live cattle. Canadian fed and non-fed cattle prices are estimated through price linkage equations where Canadian cattle prices are a function of U.S. prices (adjusted by exchange rates), lagged Canadian prices and dummy variables that break the U.S./Canadian price relationship when the U.S. border was closed to Canadian cattle. Feeder cattle prices are determined by equations that link feeder prices to slaughter cattle prices. The calf crop is determined as a fixed proportion of the breeding cow inventory. Market clearing conditions are forced to hold as prices (retail beef, fed-cattle, and non-feed-cattle) adjust to clear the market. All prices and monetary values used in the behavioural equations of the model have been deflated to account for inflation

A more detailed description of the model, as well as econometric estimation results, is provided in Appendix 1. The equations in the model are estimated using quarterly data from 1990 to 2014. Quarterly data allows one to capture important aspects of the beef market, such as seasonality and the dynamics of the market. Once all equations are estimated, the simulation model is constructed, solved and validated. The simulation treats some economic variables as fixed (including investment in marketing and research activities), but solves for the relevant endogenous variables. These endogenous (model determined) variables include:

- per capita beef disappearance in Canada and U.S. (kilograms per person)
- aggregate beef disappearance in Canada and U.S. (metric tons)
- retail price of beef in Canada and U.S. ($/lb.)
- beef exports from Canada to U.S. (metric tons)
- beef exports from Canada to the rest of world (metric tons)
- total beef production in both Canada and U.S. (metric tons)
- carcass weights in Canada (kilograms) and U.S. (lbs)
- demand for fed cattle Canada and U.S. ('000 of head)
- slaughter demand for non-fed cattle Canada and U.S. ('000 of head)
- exports of fed cattle from Canada to U.S. ('000 of head)
- exports of non-fed cattle from Canada to U.S. ('000 of head)
- supply of fed cattle in Canada and U.S. ('000 of head)
- supply of non-fed cattle in Canada and U.S. ('000 of head)
- beef cow breeding herd inventory in Canada and U.S. ('000 of head)
- price of steers for slaughter in both Canada and U.S. ($/lb.)
- price of cows for slaughter in both Canada and U.S. ($/lb.)
- price of feeder cattle in both Canada and the U.S ($/lb)

4. Check-Off Revenue and Investment in Marketing and Research

Figure 4.1 plots the flow of check-off funds (in nominal dollars) from the NCOA (and since 2012 the corresponding investments from the merged Canada Beef Inc.) to each respective division (i.e., BIC, CBEF and BCRC) for the fiscal years 2007/2008 to 2013/2014. Figure 4.1 shows a recent decline in the level of funding for market promotion. This is a period of a contracting beef herd, resulting in declining associated marketing and declining check-off funds. Holding everything else constant, if the expenditure on promotion (research) is statistically significant in affecting variables that determine industry profitability, then a downturn in expenditures will result in higher BCRs.

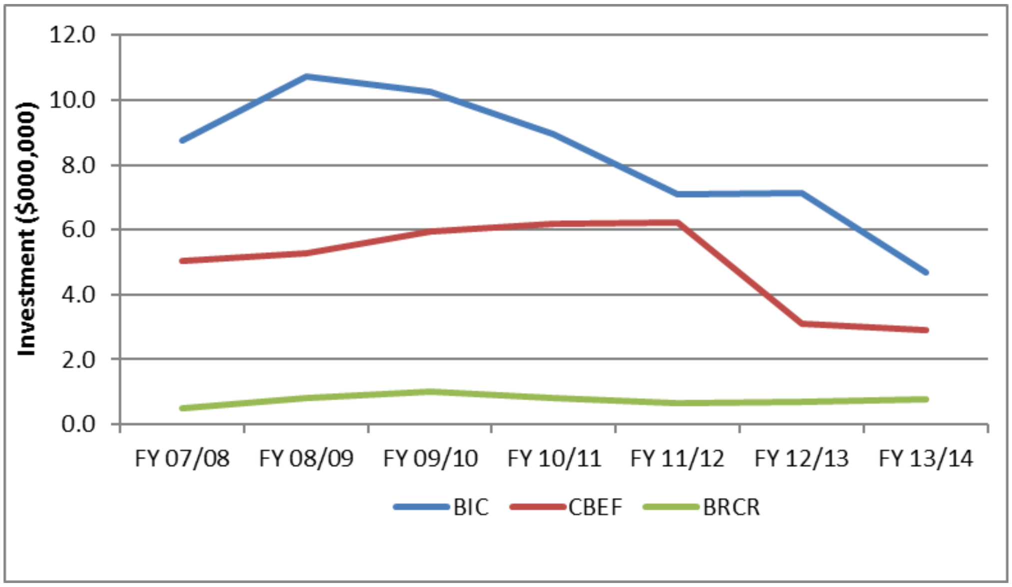

Figure 4.1. BIC, CBEF and BCRC check-off fund revenue

With respect to domestic marketing activities we followed Cranfield's general approach of only considering direct expenditures associated with promotion and research but excluding administration and operating expenses (e.g. BIC corporate planning, BIC committee, expenditures related to regional offices). However, rather than using the bottom up approach employed by Cranfield, that added up individual activities (e.g. customer service centres, processing activities, etc.)[1], we employed a top down approach that subtracted administrative and operating expenses, not directly related to activity in question, from total expenditures. This approach is somewhat cruder,[2] than the bottom up detailed approach, however we found that tracking individual expense items become difficult after the 2012 merger of BIC, CBEF and NCOA into Canada Beef. Furthermore, our approach provides a consistent accounting of the major expenditures over time as reporting procedures change. Domestic and U.S. marketing investment data were drawn from the BIC's audited financial statements from 1990 to 2011/2012 and subsequently from CCMDC Annual Implementation Plans and results reports.

Investment in international marketing activities is accounted for by market development activities only and does not include operating costs. This information is drawn from the audited financial statements for the CBEF (found in the Alberta Beef Annual Report), and since 2012 from the CCMDC Annual Implementation Plans and results reports. Investment in beef cattle research only includes investment in actual beef cattle research projects. Canfax staff in cooperation with BCRC staff provided detailed information on the timing of their investments in beef cattle research projects.

Reporting of expenditures changed with changes in the fiscal year. Following Cranfield, we made adjustments so that fiscal years consistently align over the estimation period. Annual data is divided into quarterly increments for inclusion in the model. This approach creates lumpy

[1] See Cranfield (2010) for a complete listing.
[2] We included items that Cranfield did not such as producer communications and brand management and research

expenditures that may not perfectly align with agent behaviour. This is particularly problematic for research expenditures where outcomes occur with considerable time lags and funds are transfer to researchers at periodic intervals. Investment expenditures were smoothed over the life of projects in a manner consistent with Cranfield (2010).

5. Analysis of the Economic Benefits from the Check-Off

This section reports the main results from the analysis. First we discuss how to measure producer benefits. Then we consider how to calculate reductions in marketing and research investment given that revenues only make up a portion of these total expenditures. Given this calculation we can shock the model by reducing marketing and research expenditures. Next we consider the impact of reducing these expenditures and calculate a BCR for investment of check-off funds in marketing and research. The results of our study are then discussed in the context of Cranfield's 2010 results and possible explanations for the differences are considered.

5.1. How Are Producer Benefits Measured?

Cattle producer benefits are measured in the same way as the approach used in Cranfield (2010). He defined producer surplus (i.e. profitability) as revenue from the sale of cattle minus the variable costs of production, and those are measured at a national market level. Specifically, fed-cattle producer benefits at a market level are calculated as follows:

$$CW_{Fed} \cdot (P_{Fed} - Levy - COP_{Fed}) \cdot Supply_{Fed}$$

where CW_{Fed} is carcass weight (in pounds), P_{Fed} is the price of fed cattle for slaughter (the price of slaughter steers in dollars per pound), *Levy* is the check-off levy (in dollars per pound), *COP* is the cost of production (in dollars per pound) and $Supply_{Fed}$ is the number of fed cattle (steers and heifers for slaughter).

Producer benefits for non-fed cattle are also measured as the revenue from the sale of culled cows and bulls:

$$CW_{non-fed} \cdot (P_{non-fed} - Levy) \cdot Supply_{non-fed}$$

where $CW_{non\text{-}fed}$ is the average carcass weight (in pounds) for cows and bulls, $P_{non\text{-}fed}$ is the price of slaughter cows. Following Cranfield (2012) no cost of production deduction is made because these animals are assumed to be depleted assets.

Cow calf producer benefits are measured as:

$$550 \cdot (P_{feeder} - Levy - COP_{feeder}) \cdot CCROP$$

where feeder cattle are assumed to sell at 550 pounds, P_{feeder} is the price of 550-pound feeder cattle and COP_{feeder} is the cost of production for feeder cattle. The calf crop (*CCROP*) is not measured directly but following Cranfield (2010), it is calculated as 25% of the breeding inventory of cows.

5.2 What Impact Has Historic Investment of Check-off Funds Had on Economic Benefits for Canadian Cattle Producers?

The model described in Appendix I is simulated (solved) twice: first, with the check-off dollars in place (baseline) and second with the market promotion and production research expenditures, directly associated with the check-off, removed (counterfactual). Producer benefits (described in section 5.1) are calculated using the appropriate prices and quantities from each model run. The difference between producer benefits for the counterfactual scenario and the baseline scenario measure the economic impact associated with the check-off. The benefit-cost ratio (BCR) is the ratio of the change in these benefits divided by the check-off funds removed in the counterfactual scenario. An average BCR is calculated for three different cases:

1. Removal of check-off funds from marketing activities only.
2. Removal of check-off funds from research activities only.
3. Removal of check-off funds from marketing and research activities.

Cranfield simulated the impacts for the fiscal years 2005/06, 2006/07, and 2007/08. This time period was chosen because the markets were assumed to have stabilized sufficiently after the BSE and corresponding to the time period when the Canada-U.S. border was open to trade of live cattle under-30 months of age. This study also analyzes the last three years of the model simulation - 2011/12, 2012/13, and 2013/14. This three-year period (12 quarters) corresponds to the amalgamation of the CBEF and CBI and implementation of the Science Cluster program.

5.3. How Are Reductions in Marketing and Research Investment Calculated?

Cranfield (2010) faced the problem that it was not possible to link marketing and research expenditures in any particular quarter to the check-off funds spent in that or any other previous quarter. To allocate CBEF, CBI, and BCRC expenditures that are only attributable to the check-off, Cranfield assumed “that the percentage reduction in the division’s revenue, arising from the simulated removal of check-off funds, is the same percentage reduction in that division’s investment in their respective marketing or research activities.” So he calculated the share of each division’s total revenues that were attributable to the check-off program. And he used that share to reduce BIC, CBEF and BCRC by that share in order to determine reduction expenditures that would occur if there were not check-off revenues. Table 5.3 presents an up-dated version of Cranfield’s table of check-off revenue as a percentage of total revenue.

To get an average percentage reduction and to smooth out year to year fluctuations in the reduction percentages, Cranfield dropped the highest and lowest percentages, and calculated a trimmed average for the percentage in each division’s expenditures. Using this approach, Cranfield lowered investment in domestic (Canada and the U.S.) market promotion by 49 per cent, lowered investment in international marketing activities by 37.5 per cent, and lowered investment in beef cattle research activities by 58 per cent. Applying the same approach, with up-dated shares historic domestic market promotion expenditure is reduced 52%, international market promotion is reduced by 28% and investment in beef research is reduced by 15%.

Table 5.3. Check-off revenue as a percentage of total revenue, by division

Fiscal Year	BIC	CBEF	BCRC
2009/10	41%	32%	11%
2010/11	59%	30%	10%
2011/12	49%	25%	17%
2012/13	50%	26%	21%
2013/14	52%*	NA*	15%
2014/15	53%*	NA*	15%
Average	51%	28%	15%
Min	41%	25%	10%
max	59%	32%	21%
Trimmed average	52%	28%	15%
Cranfield's trimmed average	49%	38%	58%

* After 2012 the CBEF and BIC were merged into CBI. CBI is shown as BIC share

5.3.1. Average BCR from Investment of Check-off Funds in Marketing Activities

Table 5.3.1 shows the updated calculation for the value of the reduction in marketing investment and corresponding reduction in total producer benefits (i.e., cow-calf, non-fed cattle and fed-cattle producers). The first three rows repeat Cranfield's results for FY05/06-FY07/08. The next three rows use the updated model to recalculate the BCR's over Cranfield's simulation period. While the historic calculation is reassuring in that it demonstrates that the up-dated model produces similar results to the original study, the interesting question is how the restructured NCOA, a declining beef cattle herd, and a different investment composition have affected the BCR. Therefore, the last three rows consider a simulation over the most recent period – FY 2011/12 to FY 2013/4.

This simulation period is restricted to the most recent three years in order to have a comparable time period and dynamic lag structure as were used in the Cranfield simulations. Compared to the baseline scenario, the imposed FY 2011/14 reduction in marketing expenditures resulted in a reduction in producer benefits that exceeded the reduction in investment. For FY 11/12 and FY 12/13 the BCRs are comparable with the earlier Cranfield BCRs and the results when this model was simulated over the earlier FY05/06-FY07/08 period. The slightly higher BCRs may have been a result of the re-organization and spending priorities of the NCOA. However, in FY13/14 there is a dramatic reduction in marketing expenditures over the previous two fiscal years and as a result the BCR is considerably higher. The greater loss in producer benefits can be associated with lower check-off revenues and resulting lower marketing expenditures and re-organization implications.

Table 5.3.1. Impact of reduction in check-off fund investment in marketing activities

	Reduction in investment ('000 dollars)	Reduction in Benefits ('000 dollars)	Average BCR
FY05/06*	$4,925.79	$28,877.20	5.86
FY06/07*	$5,502.26	$41,538.03	7.55
FY07/08*	$5,185.43	$43,636.65	8.43
FY05/06**	$4,925.79	$25,564.85	5.19
FY06/07**	$5,502.26	$37,030.21	6.73
FY07/08**	$5,185.43	$27,690.20	5.34
FY11/12**	$7,956.55	$74,244.51	9.33
FY12/13**	$7,721.29	$73,345.43	9.50
FY13/14**	$5,840.51	$147,254.65	25.21
NPV	$20,958.19	$284,255.29	13.56

* Cranfield (2010)
** Current study

A BCR that is greater than one implies that the benefits of the marketing activities exceed the value of the invested funds. An optimal level of investment in marketing activities would have a benefit cost ratio of one and higher BCRs imply a movement away from the optimal. Cranfield justified the growing BCRs as an adjustment to a more normal ratio that held prior to the BSE market disruption. We do not find a growing BCR in the earlier period and have to look for something else driving the growing BCR.

The shock driving the system is the reduction in BIC and CBEF expenditures, between FY11/12 and FY 13/14, reducing domestic demand and export demand in the U.S. and the rest of the world. The initial shock causes retail beef prices to decline by roughly 13% while overtime the decline modifies to 5% before declining back to 9% at the end of the simulation period. This reduction in beef prices translates initially into a one percent decline in steer prices which gradually grows to 3% towards the end of the simulation period. It is this gradual decline in farm level prices (and the associated feeder calf price) which primarily reduces farm level benefits. So it the declining steer price which is driving the increased the BCR. Cranfield's simulation period took place over a period relatively stable CBEF and BIC expenditures. Conversely the model in this study is simulated when both CBEF and BIC expenditures are in a greater state of flux and decline significantly at the end of the simulation. This is largely driving the larger reduction in producer benefits relative to the Cranfield study.

It is difficult to speculate about the large drop in the last year – is it check-off funds driven or does it reflect post-organization adjustments with the consolidation of CBEF? A longer time period subsequent to the consolidation of the CBEF, BIC and NCO is necessary to establish whether or not there is a structural change in the response to the various marketing and research activities under the new structures.

To aggregate across the simulation period, the net present value (NPV) of the reduction in investment and reduction in producer benefits is calculated assuming a three per cent discount rate and they are discounted back to the start of FY 2011/20012. In this case, the reduction in investment equals $20.9 million, while the reduction in producer benefits is $284.3 million, implying an average BCR from the entire period of 13.56:1 which compares to a ratio of 7.55:1 in the Cranfield study.

5.3.2. Average BCR from Investment of Check-off Funds in Research Activities

Holding all other production research investments constant, we examine the impact of eliminating the check-off funds that are available for basic research. Table 5.3.2 shows the reduction in production research investment and the corresponding impact on producer benefits for this scenario.

Compared to the baseline the simulated reduction in production research investments result in significantly lower producer benefits. As a consequence, the BCR is considerably greater than 1, which tells us that producers grained from the research effort even though they had to contribute check-off dollars. The first three rows repeat Cranfield's results for FY05/06-FY07/08. The next three rows use the updated model to recalculate the BCR's over Cranfield's simulation period. Clearly the average BCRs for the two models are close and very comparable. The next three rows present the most recent results for FY11/12 to FY13/14.

Table 5.3.2. Impact of reduction in check-off fund investment of beef research activities

	Reduction in investment ('000 dollars)	Reduction in Benefits ('000 dollars)	Average BCR
FY05/06*	$147.69	$5,830.92	39.48
FY06/07*	$187.93	$10,754.98	57.23
FY07/08*	$266.21	$11,978.12	44.99
FY05/06**	$147.69	$5,644.71	38.22
FY06/07**	$187.93	$11,290.83	60.08
FY07/08**	$266.21	$10,808.13	40.60
FY11/12**	$626.46	$13,987.89	22.33
FY12/13**	$661.72	$25,102.94	37.94
FY13/14**	$938.78	$38,329.56	40.83
NPV	$2,153.79	$ 74,488.97	34.58

* Cranfield (2010)
** This study

In each year the estimates of average research BCRs are in the upper end of the reasonable range of ratios suggested by Cranfield in his literature review. Cranfield made a strong case for re-allocating check-off funds away from marketing efforts toward production research. This advice appears to have been followed and the impact shows up as much higher investment expenditures in FY11/12 than in FY07/08. As a result the BCR declined from the 40:1 to 60:1 range to 22:1.

It follows that higher levels of research would correspond to lower BCRs as research expenditures are increased towards the optimal level (i.e. to result in a BCR=1). So it is reasonable that the BCR would be lower in this study than in the 2010 Cranfield study.

Eliminating these higher research expenditures has considerable lagged effects over time. So removing $626 million in the first year of the simulation has affects that are spread over more than just the initial year and these effects are compounded as an additional $662 million is eliminated in the next year. So each subsequent quarter over which the model is simulated has a correspondingly larger reduction in producer benefits[3]. Aggregating over the simulation period, using NPVs for reduced investment and reduced benefits the implied BCR is 34.6:1 which is significantly lower than Cranfield's BCR of 46:1 for the FY05/06 to FY07/08 simulation period.

5.3.3. Average BCR from Investment of Check-off Funds in Marketing and Research

This scenario assumes that the individual reductions in marketing and research that were considered above now occur simultaneously. Table 5.3.3 shows the reduction in investment in marketing and research activities, and the change in producer benefits associated with these shocks. The first three rows repeat Cranfield's results for FY05/06-FY07/08. The next three rows use the updated model to recalculate the BCR's over Cranfield's simulation period. The subsequent three rows present the most recent results for FY11/12 to FY13/14. In all periods considered the reduction in benefits exceeded the reduction in investment. So again the benefits of the check-off exceeded the costs for producers.

Table 5.3.3. Impact of reduction in check-off fund investment in marketing and research

	Reduction in investment ('000 dollars)	Reduction in Benefits ('000 dollars)	Average BCR
FY05/06*	$5,073.48	$34,593.67	6.82
FY06/07*	$5,690.19	$52,026.02	9.14
FY07/08*	$5,451.65	$55,310.77	10.15
FY05/06**	$5,073.48	$33,129.82	6.53
FY06/07**	$5,690.19	$54,113.71	9.51
FY07/08**	$5,451.65	$47,592.90	8.73
FY11/12**	$8,583.02	$83,356.80	9.71
FY12/13**	$8,383.01	$91,731.80	10.94
FY13/14**	$6,779.28	$165,112.58	24.36
NPV	$23,111.98	$328,051.25	14.19

* Cranfield (2010)
** This study

The implied average BCRs for market promotion and production research investments, for the most recent period range from 9.7:1 to 24.3:1. This range is significantly higher at the top end then the range provided by Cranfield (6.8:1 to 11:1). One reason for the difference can partially be explained by the significant decline in marketing promotion expenditures at the end of the current simulation period. Other differences in impacts could have resulted from unobserved

[3] The model is not simulated over a sufficiently long enough period of time for this compounding effect to have subsided.

differences in modeling approaches, a change in investment expenditures between the two study periods, and a fundamental change in the management of the BIC and CBEF. The effect of reducing research investment certainly has a significant lagged impact and with this lagged impact BCRs tend to increase over time as the benefits cumulate. This affect may account for a moderate increase in the BCRs over time and a longer simulation period may have ameliorated some of end of period BCR escalation if the model were allowed sufficient time to completely adjust.

6. Summary and Conclusions

This research project evaluated the economic impact of investing Canadian cattle producer check-off dollars in marketing and research activities. The analysis focused on updating the 2010 Cranfield estimates of historic producer returns to investment in marketing and research activities. Cranfield's BCR (especially for production research) were at the upper range of prior estimates (from other studies). The question was whether Canadian BCR are still at the high end of the range.

To provide answers to this question, an econometric simulation model was developed. This model mimics the workings of North American beef and cattle markets and explicitly accounts for check-off investments marketing and production research. Cranfield's analysis showed that Canadian cattle producers gain from marketing and research investments. He showed that between 2005 and 2008 the benefit-cost ratio (BCR) associated with check-off expenditures on marketing and research activities grew from 7:1 to 11:1. The analysis in this study showed a range of BCRs from 10:1 to 24:1. However, the results are more consistent than they may appear a first glance. The 24:1 ratio relates only to the last year of the simulation and otherwise the BCRs are closer in magnitude. The high BCR falls in a period with declining promotion expenditures, a change in strategic focus as the Canada Beef Inc. adjusts to the consolidation of BIC, CBEF and the NCOA.

Canada Beef Inc. has been focusing presenting beef as a differentiated product rather than a commodity. Export promotion attempts to focus on specific markets (e.g. U.S. ethnic markets) in an attempt to promote lower priced cuts such as heavy middle meat and thin meats. Differences in grading between Canada and the create a challenge that for example, more Canadian AAA beef should be considered as U.S. Choice. Establishing equivalency of grades will help Canadian exports extract more value from the U.S. market. Actions such as these are not product differentiation in the conventional sense but they do attempt to create more value for Canadian products. The problem with the modelling approach used in this study, and in the previous study by Cranfield, involves a blunt instrument which models very aggregated markets instead of the subtleties of the change in focus by Canada Beef Inc.

Certainly one necessary condition for product differentiation is production research that can create new and innovative products. Cranfield's estimates of BCR for production research were at the high end of the range of prior estimates. This study tended to produce lower BCR for research investments than the 2010 study by Cranfield. This may be an artifact of the model, but it may also reflect higher research expenditures and more successful research expenditures in the latter period.

References

Alston J.M., M.C. Marra, P.G. Pardey, T.J., and Wyatt, 2000, "Research returns redux: a meta-analysis of the returns to agricultural R&D" *Australian Journal of Agricultural and Resource Economics* 44 (2): 185-215.

Cranfield J., 2010, "Evaluating the Economic Benefits From the Canadian Beef Check-Off" www.canadabeef.ca/wp-content/uploads/2015/04/Check-off-full-study.pdf

Gray R. and S. Malla, (2007) "The Rate of Return to Agricultural Research in Canada" CAIRN Policy Brief, Canadian Agricultural Innovation Research Network, http://www.ag-innovation.usask.ca/final%20policy%20briefs/MallaGray_11.pdf

Appendix 1: Econometric Simulation & Baseline Validation

RETAIL DEMAND

Retail demand in Canada is modelled on a per capita basis as follows:

$$
\begin{aligned}
PCBD3 = \alpha_1 &+ \beta_{11}Q_1 + \beta_{12}Q_2 + \beta_{13}Q_4\beta_{16}RPB3/CPI + \beta_{14}RPPK3/CPI + \\
&+ \beta_{15}RPCK3 + \beta_{16}PCDY3/CPI + \beta_{17}PCBD3(-1)/CPI \\
&+ \beta_{18}(1/BIC\ \exp(-1)) + \beta_{19}(1/Branded\ (-1)) + \beta_{201}BSE_{03-2}
\end{aligned}
$$

where *PCBD3* is per capita quarterly disappearance of beef (carcass weight) in Canada, *Q1 - Q4* are quarterly seasonal dummies, , *PCDY3* is deflated Canadian per capita disposable expenditure, *RPB3* is the retail price of beef in Canada (C$ per pound), *RPPK3* and *RPCK3* are consumer price indexes (CPI's 2002=100) for Canadian pork and chicken *PCBD3(-1)* is the lagged per capita disappearance and α and β's are parameters to be estimated. The variable $1/BIC\ \exp(-1)$ is the inverse of real capita *BIC* marketing investment in Canadian beef marketing. The variable $1/Branded$ controls for the effect of branded advertising. Both terms enter as an inverse term to allow advertising to affect consumption at a rate that increases at decreasing rate. Therefore, the expected sign is negative. A lagged dependent variable (LDV) is included to allow for partial adjustment in consumption over time. Per capita disposable expenditure and the retail price of beef are deflated using the CPI (2002=100).

The variable *BIC exp* term includes investment in marketing initiatives aimed at increasing demand for beef in Canada. It is calculated at total BIC expenditures less administrative and operating expenses

$$
\begin{aligned}
PCBD4 = \alpha_2 &+ \beta_{21}Q_1 + \beta_{22}Q_2 + \beta_{23}Q_4 + \beta_{24}T + \beta_{24}RPB4/CPI4 + \\
&\beta_{25}RPPK4/CPI4 + \beta_{26}RPCK4/CPI4 + \beta_{27}PCDY4/CPI4 + \beta_{28}PCBD4(-1)
\end{aligned}
$$

where *PCBD4* is per capita quarterly disappearance (pounds) of beef (carcass weight) in the U.S., *PCDY4* is deflated U.S. per capita disposable income, *RPB4* is the deflated U.S. retail price of beef (U.S.$ per pound), *RPPK4* is the deflated U.S. retail price of pork (U.S. $ per pound) and *RPCK4* is the deflated U.S. retail price of chicken (U.S. $ per pound). A lagged dependent variable (LDV) is included to allow for partial adjustment in consumption over time. Per capita disposable income and the retail prices of beef, pork and chicken are deflated using the CPI (1982-84= 100). Table A.1 shows summary statistics of the variables used for the estimation.

Table A.2 shows OLS estimates and elasticities for the Canadian and U.S. retail demand function. The adjusted R^2 statistic indicates that the equations both the Canadian and U.S retail beef demand equations track actual per capita disappearance and carry statistical significance. The signs of the parameters for both countries equations are the correct sign. The beef price (negative sign) and disposable income (positive sign) parameters are statistically significant. Beef demand is inelastic for both countries. The elasticity of retail beef demand in Canada with respect to BIC expenditures is positive and indicates that a one per cent increase in investment in beef marketing activities in Canada brings about a 0.049 per cent increase in demand for beef in Canada. This parameter is somewhat larger than the 0.023 elasticity reported by Cranfield. A variable has been added to control for branded advertising but it is not statistically significant. Table A2.1 compares elasticities between studies.

Table A.1 Summary statistics of data used for estimation: 1990:1-2014:4

Variable	Units	Mean	St. Dev.
pcbfd3	kg/head	8.030	0.670
RPB3	deflated $ pound	3.550	1.243
RPPK3	cpi Index	101.315	12.150
RPCK3	cpi Index	108.901	21.797
PCDY3	10,000 per person	21.432	2.576
SH3	'000 head	695.675	199.829
MSH3	'000 head	817.644	167.549
IBW3	'000 head	4,741.710	91.388
CB3	'000 head	149.794	34.737
MCB3	'000 head	198.149	45.479
PSS3	Delfated $/lb	1.031	0.231
PFC3	Delfated $/lb	1.242	0.290
PCB3	Delfated $/lb	0.669	0.248
XBFROW	‘000 kg	9,874.553	7,127.048
XBF34	‘000 kg	62,499.745	23,325.359
CWSH3	(pounds)	813.768	24.794
EXSC13	'000 head	142.821	68.040
EXBC13	'000 head	50.908	34.892
PCBD4	kg/head	10.464	0.725
RPPB4	deflated $ pound	1.998	0.192
RPPK4	deflated $ pound	1.485	0.100
RPCK4	deflated $ pound	1.010	0.217
PCDY4	Delated $ per person	15,317.427	1,453.762
SHS3	'000 head	6,293.690	297.964
MSH3	'000 head	6,192.049	302.037
ICB	'000 head	42,219.123	1,785.436
CBS3A	'000 head	1,671.561	144.503
MCB3	'000 head	1,589.208	144.095
PS4	deflated $ pound	0.465	0.075
PC4	deflated $ pound	0.278	0.064
PFC4	deflated $ pound	0.625	0.133
fp4	deflated $ pound	0.043	0.015

Table A2. OLS estimates of the per capita retail disappearance equations for Canada and the United States

	Canada			U.S.			
Variable	Coef	(t-stat)	Elasticity	Coef	(t-stat)	Elasticity	
Intercept	0.011***	(8.381)		12.465***	(3.97)		
Q1	-0.001*	(-4.637)		-1.129***	(-7.44)		
Q2	0.000	(0.278)		0.044	(0.27)		
Q4	-0.001***	(-4.355)		-1.214***	(-10.19)		
Trend				-0.096***	(-7.51)		
beef price	-0.0007***	(-3.186)	-0.300	-2.126***	(-4.33)	-0.185(sr)	-0.218(lr)
pork price	-0.0009	(-0.972)	-0.109	0.280	(0.35)	0.018(sr)	.0.021lr)
chicken price	-0.0005	(-0.446)	-0.064	-2.031	(-1.03)	-0.054(sr)	-0.063(lr)
per capita income	0.0000001**	(2.212)	0.232	0.001***	(6.66)	0.930(sr)	1.096(lr)
Inverse of BIC expend	-0.0000002**	(-1.969)	0.053				
Inverse Branded expd	-0.0000000	(-0.318)	0.000				
Dummy BSE (03)	0.00107***	(7.048)					
LDV				0.150***	(1.256)		
Sample	1990:1-2014:4			1990:1-2014:4			
Adj- R^2	0.579			0.926			
DW	2.076			1.505			

SR - short run elasticity and LR – long run elasticity***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A2.1 Elasticity comparison

	Canada		U.S.	
	This study	Cranfield	This study	Cranfield
beef price	-0.300	-0.289	-0.185	-0.196
pork price	-0.109	-0.003	0.018	0.002
chicken price	-0.064	2.62	-0.054	-0.009
per capita income	0.232	0.0002	0.930	0.637
BIC expend	0.053	0.023		

DEMAND FOR SLAUGHTER STEERS AND HEIFERS

Steer and heifer (i.e., fed cattle) slaughter in Canada is modelled as a derived demand:

$$SHS3 = \alpha_3 + \beta_{31}Q_1 + \beta_{32}Q_2 + \beta_{33}Q_4 + \beta_{34}T + \beta_{35}RPB3/WL1 + \beta_{36}PS3/WL1 + \beta_{37}dumBSE + \beta_{38}SHS3(-1) + \beta_{39}trend$$

where *SHS3* is commercial steer and heifer slaughter in Canada (‘000 head), PS3 is the deflated price of steers in Alberta (C$ per pound), WL3 is the deflated quarterly wage for employees paid by the hour in meat packing and processing plants in Canada (CND$), *SHS3(-1)* is the lagged commercial Canadian slaughter of steers and heifers, a dummy variable that is used to account for BSE and a time variable is included to account for industry trends.

$$SHS4 = \alpha_4 + \beta_{41}Q_1 + \beta_{42}Q_2 + \beta_{43}Q_4 + \beta_{44}RPB4/WL4 + \beta_{45}PS4/WL4$$
$$+ \beta_{46}SHS4(-1)$$

where *DSH4* is commercial steers and heifers slaughter in the U.S. ('000 head), *PS3* is the deflated price by the quarterly wage rate for meat packing and processing plants in the U.S. (U.S.$), *SHS4(-1)* is the lagged commercial slaughter of steers and heifers in the U.S. and other variables are as defined before. Results are summarized in Table A.3 below.

Table A.3. OLS estimates of the steer and heifer slaughter equations for Canada and the United States

	Canada				U.S.			
Variable	Coef	(t-stat)	Elasticity		Coef	(t-stat)	Elasticity	
Intercept	115.033	(1.722)			6274.810***	(9.787)		
Q1	24.038	(1.829)			-699.860***	(-7.235)		
Q2	88.265***	(7.152)			18.669	(0.257)		
Q4	-35.75***1	(-2.937)			-628.319***	-6.678		
Retail price/wage	257612.000	(1.484)	0.192(sr)	0.211(lr)	1558.780**	(2.134)	0.073(sr)	0.091(lr)
steer price/wage	-1462700.00***	(-3.459)	-0.283(sr)	-0.311(lr)	-12010.200***	(-3.851)	-0.130(sr)	-0.130(lr)
Dummy 03:2-05:3	-59.411***	(-3.140)						
LDV	0.910***	(18.761)			0.203**	(2.136)		
sample	1990:1-2014:4				1990:1-2014:4			
Adj R^2	0.846				0.720			
Durbin-h	2.090				0.710132			

SR - short run elasticity and LR – long run elasticity***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A3.1 Elasticity comparison (slaughter fed cattle)

	Canada				U.S.			
	This study		Cranfield		This study		Cranfield	
Retail price/wage	0.192(sr)	0.211(lr)	0.137(sr)	0.683(lr)	0.073(sr)	0.091(lr)		
steer price/wage	-0.283(sr)	-0.311(lr)	-0.27(sr)	-1.025(lr)	-0.130(sr)	-0.130(lr)	-0.209(sr)	-0.374(lr)

The overall fit (adjusted R^2) for the Canadian and U.S. steer and heifer slaughter equations is relatively good. However, the Durbin *h* statistics (used to test for autocorrelation in the presence of a lagged dependent variable) suggest the estimated models may suffer from autocorrelation. As in the Cranfield study no correction for autocorrelation is attempted. The intercept and coefficients on the seasonal dummy variables indicate significant quarterly variation in steer and heifer slaughter, while dummy variables accounting for the under thirty month (UTM) border closure is statistically significant in the Canadian equation. While the retail price coefficient in the derived demand equation for Canada was only significant at the 14% level, the variable was not removed for theoretical reasons (when removed the magnitude of the other coefficients changed), suggesting its removal would result in an omitted variable bias. Coefficients on the price of slaughter steers are significant and negative, as expected, in both equations. Lastly, the lagged dependent variable in each country's steer and heifer slaughter equation is significant. Table A.3.1 compares elasticities in this study with Cranfield.

DEMAND FOR SLAUGHTER COWS AND BULLS

Cow and bull slaughter in Canada is also modelled as a derived demand:

$$CBS3 = \alpha_5 + \beta_{51}Q_1 + \beta_{52}Q_2 + \beta_{53}Q_4 + \beta_{53}RPB3/WL1 + \beta_{54}PC3/WL1 \\ + \beta_{55}BSE_{border\ closure} + \beta 5CBS3(-1)$$

where *CBS3* is commercial cow and bull slaughter ('000 head) in Canada, *PC3* is the deflated price of cows in Alberta (C$ per pound), *CBS3(-1)* is the lagged commercial slaughter of cows and bulls in Canada and the dummy variable account for the border closure for OTM animal exports to the U.S.

$$CBS4 = \alpha_6 + \beta_{61}Q_1 + \beta_{62}Q_2 + \beta_{63}Q_4 + \beta_{65}PC4/WL4 + \beta_{68}CBS4(-1)$$

where *CBS4* is commercial cow and bull slaughter in the U.S. ('000 head), *PC4* is the deflated price of cows in the U.S. (US$ pound), *CBS4(-1)* is the lagged commercial slaughter of cows and bulls and other variables are as defined before. Results are summarized in Table A.4.

Table A.4. OLS estimates of the cow and bull slaughter equations for Canada and the United States

	Canada				U.S.			
Variable	Coef	(t-stat)	Elasticity (SR)		Coef	(t-stat)	Elasticity	
Intercept	59.030***	(4.029)			125.843	(1.066)		
Q1	13.791**	(2.105)			-223.364***	(-8.418)		
Q2	-0.070	(-0.011)			-100.74***	(-4.176)		
Q4	41.5325***	(6.390)			149.412***	(6.001)		
Retail price/wage	14.314	(1.508)	0.339(sr)	0.823(lr)	57.3107	(0.764)	0.069(sr)	0.076(lr)
cow price/wage	-224.152***	(-3.026)	-0.847(sr)	-2.054(lr)	-119.129	(-0.547)	-0.022(sr)	-0.024(lr)
Dummy 03:2-07:3	-52.701**	(-2.248)						
Post-BSE trend	0.6906	(1.245)						
LDV	0.58775***	(7.692)			0.905***	(22.429)		
sample								
Adj R2	0.635				0.829			
Durbin's h	-2.963				-0.097			

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A4.1 Elasticity comparison (non-fed slaughter cattle)

	Canada				U.S.			
	This study		Cranfield		This study		Cranfield	
Retail price/wage	0.339(sr)	0.823(lr)	0.105 (sr)	0.429 (lr)	0.069(sr)	0.076(lr)		
cow price/wage	-0.847(sr)	-2.054(lr)	-0.153 (sr)	-0.629(lr)	-0.022(sr)	-0.024(lr)	-0.088(sr)	-0.345(lr)

The estimated cow and bull slaughter equations for the U.S. fit the data well while the adjusted R^2 suggests that the Canadian equation only explains 64% of the variation in the Canadian dependent variable. Given the disruptions to the Canadian cow market as a result of the BSE border closures the fit is reasonable. The low value of Durbin's h statistic for the U.S. indicates that we cannot reject the null hypothesis of no first order autocorrelation. The same conclusion does not hold for the Canadian equation but no attempt to control for autocorrelation has been attempted for reasons explained previously. The intercept and coefficients on the seasonal dummy variables indicate significant seasonal variation in cow and bull slaughter in both countries. As expected, the coefficient on Dummy 03:2-07:3 variable (for the prolonged BSE border closure) in the Canadian equation is negative and significant reflecting the marked reduction in cow and bull slaughter immediately after the 2003 BSE event. While the retail price coefficient in the derived demand equation for Canada is only significant at the 13% level, the variable was retained for theoretical reasons, and so as not to bias the other parameters as result of its removal. In the U.S. the retail price is not significant and this may be the reason why Cranfield chose to remove this variable from his U.S. specifications. Cranfield found that not only was the coefficient on the retail price in the Canadian non-fed slaughter equation not significant, but the elasticity with respect to this price was inelastic in both the short and long run. This is consistent with our results (see table A4.1). The cow price variable is negative significant for the Canadian model as would be expected in a slaughter demand equation. Cranfield found that short and long run elasticities of non-fed slaughter with respect to the price of slaughter cows were inelastic in both equations, but are more inelastic in the U.S. than for Canada. We found the opposite and this may reflect the different cattle market conditions that occurred in the two countries. Lastly, the lagged dependent variables are also significant in each country's equation.

SLAUGHTER STEER AND HEIFER SUPPLY

Slaughter steer and heifer supply (marketings) in Canada is modelled as follows:

$$SH3 = \alpha_7 + \beta_{71}Q_1 + \beta_{72}Q_2 + \beta_{73}Q_4 + \beta_{75}PS3(-2)/FP1(-2) + \beta_{77}IBC3(-8) \\ + \beta_{79}BCRC(-4) + \beta_{79}BCRC(-4) + \beta_{76}BSE_{dummy}$$

where *SH3* is supply (marketed number) of steers and heifers in Canada ('000 head), *PS3(-1)* is the lagged deflated price of steers, *FP* is the two period lagged Canadian price of barley (C $ per tonne), IBC3(-8) is the lagged inventory of Canadian beef cows ('000 head). *BCRC* is Beef cattle research expenditures

Steer and heifer supply in the U.S. is modelled as follows:

$$SH4 = \alpha_8 + \beta_{81}Q_1 + \beta_{82}Q_2 + \beta_{83}Q_4 + \beta_{85}PF34(-3) + \beta_{86}FP4(-3) + \beta_{86}IBC4(-8) + \beta_{89}SH3(-1)$$

where *SH4* is supply of steers and heifers in the U.S. (‘000 head), *IBC3* is inventory of beef cows in the U.S. (‘000 head), *PFC4(-3)* is the lagged deflated price of U.S. feeder calves, *FP4(-3)* is the lagged deflated price of corn in in the U.S. (US$ per bushel), SH4(-1) is the lagged supply of steers and heifers and other variables are as defined before. Results are summarized in Table 4.

Table A.5. Estimates of the steer and heifer supply equations for Canada and the U.S.

	Canada			U.S.			
Variable	Coef	(t-stat)	Elasticity	Coef	(t-stat)	Elasticity	
Intercept	199.216*	(1.640)		235.508	(0.385)		
Q1	-84.6923***	(-4.038)		-305.438***	(-4.053)		
Q2	-29.1952	(-1.392)		296.356***	(3.576)		
Q4	-46.1358**	(-2.200)		-487.885***	(-8.484)		
steer/feed price	11531.2****	(2.589)	0.115				
feed price				-2876.39	(-1.85)	-0.019(sr)	-0.036(lr)
Cow inventory (-8)	0.129755***	(5.059)	0.734	1.06E-04***	(4.58)	0.524(sr)	1.003(lr)
BCRC (-4)	1.22E-09	(1.434)	0.019				
BCRC(-20)	1.38E-09	(1.218)	0.0001				
Dummy	-4.163***	(-2.793)					
LDV				0.478	(5.365)		
sample	1990:1-2014:4			1991:1-2014:4			
Adj R^2	0.5917			0.818			
Durbin's h	1.1791 (DW)			2.159			

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A5.1 Elasticity comparison (fed cattle marketing supply)

	Canada			U.S.			
	This study	Cranfield		This study		Cranfield	
steer/feed price	0.115		0.429 (lr)				
feed price		-0.101 (sr)	-0.350(lr)	-0.019(sr)	-0.036(lr)	-0.035(sr)	-0.070(lr)

The estimated steer and heifer supply equations fit the U.S. data relatively better than the equation for Canada fits the data. The ratio of steer to barley prices is positive and statistically significant for the Canadian supply equation. The dummy variable BSE crisis on Canadian fed-cattle sales is significant and negative. BCRC investment is lagged one year and years to account for the slow realization and adoption of innovations. It is relatively difficult to get a statistically significant fit for these variables. We were only able to get significance at the 16 and 25 percent levels but this is not dissimilar to what was found in Cranfield.

.

The elasticities for the Canadian equation show steer and heifer supply to be inelastic with respect to the steer/feed price ratio; inelastic with respect to beef cow inventories; and inelastic to beef cattle research investment (in the short- and long run). Note too, that the supply of slaughter steers and heifers is more responsive to changes in the beef cow herd than to the steer feed price ratio.

In the U.S. version of the steer and heifer supply model, coefficients on all seasonal dummy variables, the price of feed corn, the lagged inventory of beef cows, and the lagged dependent variable are significant at the five per cent level or better. Furthermore, the feed price effect is negative, while the beef cow inventory effect is positive, as expected. The own-price elasticity suggests that the U.S. supply of slaughter steers and heifers is inelastic with respect to the price of feed and the beef cow herd, in both the short and long run. This is consistent with Cranfield's findings. Our elasticities are roughly half the size of Cranfield's elasticities. Note too, that the supply of slaughter steer and heifers in the U.S. is more responsive to changes in the beef cow herd than the price of feed.

COW AND BULL SUPPLY

Slaughter cow and bull supply in Canada is modelled as follows:

$$CB3 = \alpha_9 + \beta_{91}Q_1 + \beta_{92}Q_2 + \beta_{93}Q_4 + \beta_{94}T + \beta_{95}PC3/CPI + \beta_{96}FP3/CPI + \beta_{97}IBC3(-1) + \beta_{98}\text{DUM\_0302\_O503} + \beta_{99}\sqrt{BCRC}(-4)$$

where *CB3* is cow and bull supply (marketings) in Canada ('000 head), PC3 is the deflated price of cull cows (CND $ per pound), IBC3(-1) is the lagged inventory of beef cows in Canada ('000 head), and is included to account for herd dynamics, $\sqrt{BCRC}$ is the square of BCRC research expenditures, CB3(-1) is the lagged supply of cows and bulls in Canada and other variables are as defined as before.

The supply equation for slaughter cows and bulls in the U.S. is modelled as follows:

$$CB4 = \alpha_{10} + \beta_{101}Q_1 + \beta_{102}Q_2 + \beta_{103}Q_4 + \beta_{104}PC4/CPI + \beta_{105}PFC4/CPI + + \beta_{106}CB4(-1)$$

where *CB4* is U.S. cow and bull supply ('000 head), *PC4* is the price of culled cows, *PFC4* is the deflated price of U.S. feeder calves in the U.S. (US $ per pound), and *CB4(-1)* is the lagged supply of cows and bulls in the U.S. and other variables are as defined as before. Results are summarized in Table A.6

The estimated slaughter cow and bull supply equations fit the data moderately well. The Canadian estimates are more problematic with a lower level of overall fit. Durbin's h-test and DW for Canada do not indicate first-order autocorrelation. Our equations produced more significant correctly signed variables than Cranfield's results showed. Cow price and feeder calf prices both are correctly signed and statistically significant at the 1% level. The square root of

BCRC expenditure is correctly signed and statistically significant. The 4 quarter lag seems very short.

Table A.6. OLS estimates of the cow and bull supply equations for Canada and the U.S.

	Canada			U.S.			
Variable	Coef	(t-stat)	Elasticity	Coef	(t-stat)	Elasticity	
Intercept	-1.830	(-0.022)		558.711***	(4.219)		
Q1	44.885***	(5.009)		-112.204***	(-4.674)		
Q2	11.494	(1.305)		-71.373***	(-3.505)		
Q4	69.512***	(7.164)		146.081***	(6.466)		
cow price	233.657***	(3.489)	0.667	505.941*	(1.984)	0.087	0.340
feeder calf price	-108.475***	(-4.773)	-0.680	-449.089***	(-3.894)	-0.175	-0.681
Cow inventory (-8)	0.039**	(2.626)	0.869				
Dummy	-52.738***	(-3.482)					
BCRC_sqr(-4)	0.035*	(1.998)	0.034				
LDV				0.742811***	(8.665)		
sample	1990:1-2014:4			1990:1-2014:4			
Adj R2	0.575			0.752			
Durbin's h	1.910			-0.134			

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A6.1 Elasticity comparison (non-fed cattle marketing supply)

	Canada		U.S.			
	This study	Cranfield	This study		Cranfield	
cow price	0.667		0.087	0.34		
feeder calf price	-0.68		-0.175	-0.681	-0.448(sr)	-0.891 (lr)

The U.S. model fit almost as well as the Canadian cull supply equation. All the explanatory variables are significant. The feeder-calf price effect is negative and significant. The short run elasticities suggest that the supply of slaughter cows and bulls is inelastic with respect to the relevant price variables. Where available the Cranfield elasticity estimates are comparable to this study. In general, the supply of slaughter cows and bulls is more responsive to changes in the beef cow herd than to the price of feeders or the price of cows.

BEEF COW INVENTORY

The size of the beef cow herd, an indicator of the potential size of the calf crop and hence steer and heifer slaughter in future periods, is modelled as follows for Canada:

$$IBC3 - IBC3(-1) = \alpha_{11} + \beta_{111}Q_1 + \beta_{112}Q_2 + \beta_{113}Q_4 + \beta_{114}PFC13(-8) + \beta_{115}SCB1(-1)$$

The inventory of Canadian breeding cows *IBC3* proved difficult to estimate for Canada. Rather than using Cranfield's approach and estimating the dependant variable as the level the current inventory we chose to estimate this variable as a first difference of inventories between quarters. Prior period marketings of cull animals is included to account for the decline in the herd as older cows are marketed putting pressure for replacements.

The beef cow herd in the U.S. is modelled as:

$$IBC4 - IBC4(-1) = \alpha_{12} + \beta_{121}Q_1 + \beta_{122}Q_2 + \beta_{123}Q_4 + \beta_{125}PFC4(-10) + \beta_{126}WK4(-10) + \beta_{127}trend$$

The inventory of U.S. breeding cows is estimated in a similar manner to the Canadian equation. The difference is the real interest rate *WK4* is included to account for the opportunity cost of holding a capital asset (breeding stock). Other variables are as defined before. Results for the equations for inventory of beef cows are summarized in Table 6.

Table A.7. Estimates of the beef cow herd inventory equations for Canada and the U.S.

Dependent variable = Inventory(t)– Inventory (t-1)						
	Canada			U.S.		
Variable	Coef	(t-stat)	Elasticity	Coef	(t-stat)	Elasticity
Intercept	-31.045	(-0.340)		-578.55***	(-3.759)	
Q1	179.029***	(4.858)		609.42***	(15.579)	
Q2	167.337***	(4.352)		618.95***	(14.597)	
Q4	-7.014	(-0.202)		-1.89	(-0.053)	
feeder calf price(-8)	83.860*	(1.708)	0.020	426.82***	(4.251)	0.008
feed price(-8)				-2388.31**	(2.037)	0.003
interest rate(-8)				-3.17	(0.399)	0.001
cow marketings(-1)	-0.772**	(-2.147)	-0.038			
time				-1.589**	(-2.463)	
sample	1990:1-2014:4			1990:1-2014:4		
Adj R^2	0.266			0.828		
DW	1.877			0.018 (Durbin h)		

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

The relatively low adjusted R^2 reflects the fact that the dependent variable is measured in first differences. Lagged feeder calf price variables are positively signed and significant for both countries. However, the short- and long run elasticity of beef cow herd size with respect to the price of feeder calves prices is very inelastic. This is consistent with Cranfield short elasticities of 0,001 and .011 for the long run. As Cranfield suggests herd dynamics are more important than the output prices for breeding herd development.

CARCASS WEIGHT EQUATION

The equation for carcass weights of slaughter cattle in Canada is as follows:

$$CWS3 = \alpha_{13} + \beta_{131}Q_1 + \beta_{132}Q_2 + \beta_{133}Q_4 + \beta_{134}PS3(-6) + \beta_{135}BCRC(-4) + \beta_{136}BCRC(-4)^2$$

where CWS3 is weighted average carcass weight of steers in Canada (pounds) and CWS1(-1) is the lagged dependent variable and other variables are defined as before.

Table A.8. OLS estimates of the carcass weight equation for Canada

	Canada		
Variable	Coef	(t-stat)	Elasticity
Intercept	760.164***	(29.513)	
Q1	-8.169	(-1.029)	
Q2	-36.704***	(-4.810)	
Q4	6.325	(0.835)	
price steers (-6)	0.359	(1.316)	0.041
BCRC (-2)	1.07E-04***	(3.816)	0.010
BCRC (-16)	9.34E-05***	(2.448)	0.005
sample	1990:1-2014:4		
Adj R^2	0.574		
Durbin-h	0.3231		

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

The estimated carcass-weight equation for Canada fits the data reasonably well. The intercept, and coefficient on the Q2 dummy variables are significant. The lagged price of steers is not, although it has the correct sign. The elasticity of carcass weights with respect to research investment is statistically significant for 2 and 16 quarters but is very inelastic. However, the short run (2 quarter) is elasticity is 10 times larger than the elasticity obtained by Cranfield (0.001) and in the case of this study the elasticity is statistically significant. The reader should not that this study did not include a lagged dependent variable to account for partial adjustment. The Cranfield study did account for a partial adjustment process. When we attempted to include a lagged dependent variable the research expenditure variables were not significant. The addition of 4 year lagged BCRC variable accounts for the longer run adjustment but does not treat the lagged adjustment process as infinite.

CANADA-U.S. PRICE LINKAGE

To capture the economic relationship between the Canadian and U.S. beef cattle sectors, they are linked through a price linkage equation at the farm level, specifically using the price of slaughter steers (i.e., fed cattle). It is important to recognize that a farm-level price linkage relationship will not hold when the Canada-U.S. border is closed to live cattle trade. To account for this situation, individual dummy variables are included for each affected quarter which force the Canadian price to equal it actual value in that period and the coefficient are representative of the period when the Canada-U.S. border was open to live cattle under 30 months of age. Because of the large number of dummied out coefficients are not shown in Table A.9. An additional dummy variable is included to account for the presence of Mandatory Country of Origin Labelling in the U.S. The following Canada-U.S. farm fed cattle price linkage equation is estimated:

$$PS3 = \alpha_{21} + \beta_{211}Q_1 + \beta_{212}Q_2 + \beta_{213}Q_4 + \beta_{214}(PS4 * ER) + \beta_{215}PS3(-1) + \beta_{216}time$$
$$+ seven\, dummies\, for\, a\, closed\, border \quad + \beta_{2113}Dummy_{MCOOL:}$$

Where the variables are as previously defined and *ER* is the Canada –U.S. exchange rate (C$/US$) Results are summarized in Table A.9.

A similar equation is specified for price linkage for the price of cull cows between Canada and the U.S. The market was disconnected for a much longer period of time than the UTM market The following Canada-U.S. retail price linkage equation is estimated:

$$PC3 = \boldsymbol{\alpha}_{21} + \boldsymbol{\beta}_{221}Q_1 + \boldsymbol{\beta}_{222}Q_2 + \boldsymbol{\beta}_{223}Q_4 + \boldsymbol{\beta}_{212}(PC4 * ER) + \boldsymbol{\beta}_{225}PC4(-1)$$
$$+ seventeen\, dummies\, for\, a\, closed\, border$$

Table A.9. OLS estimates of the Canada-U.S. price linkage equation

	Canada Steer price				Canada cow price			
Variable	Coef	(t-stat)	Elasticity		Coef	(t-stat)	Elasticity	
Intercept	3.885	0.592			-7.145***	-2.743		
Q1	4.510***	2.441			6.014***	3.743		
Q2	2.292	1.296			3.288**	2.193		
Q4	3.606*	1.945			-4.639***	-3.173		
Price in US	0.556***	5.180	0.698(sr)	1.060(lr)	0.410***	6.591	0.466(sr)	1.543(lr)
time	-0.034	-1.135						
lagged Cdn price	0.341***	2.743			0.698***	10.544		
Dummies to account for the breakage in price linkage due to border closure								
dummy MCOOL	0.365	1.985						
sample	1990:1-2014:4				1990:1-2014:4			
Adj R^2	0.683				0.942			
Durbin-h	0.328				3.332			

SRE - short run elasticity and LRE – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

There is a positive and significant relationship between the Canadian price of slaughter steers and the U.S. price of slaughter steers the long run price transmission elasticity is one as expected. This is the same result that Cranfield found. The short run price transmission elasticity is also significant, but only 0.7 so not all U.S. price variability is transmitted into Canada. A similar relationship holds for cow price transmission elasticities, however there is some price overshooting with a long run elasticity of 1.5. This may reflect an overshooting where Canadian cull prices over respond to changes in the U.S. market.

FARM PRICE LINKAGE EQUATIONS

The relationship between the price of slaughter steers and the price of feeder calves is captured via the following equations for Canada and the U.S., respectively:

$$PFC3 = \alpha_{23} + \beta_{231}Q_1 + \beta_{233}Q_2 + \beta_{233}Q_4 + \beta_{234}T + \beta_{235}PS1 + \beta_{236}FP1 + \beta_{237}PFC1(-1)$$

$$PFC4 = \alpha_{24} + \beta_{241}Q_1 + \beta_{24}2Q_2 + \beta_{243}Q_4 + \beta_{244}T + \beta_{245}PS3 + \beta_{274}FP3 + \beta_{247}PFC3(-1)$$

Variables are as defined as before. Results are summarized in Table 13.

Table A.12. Estimates of the feeder-calf price linkage equations for Canada and U.S.

	Canada				U.S.			
Variable	Coef	(t-stat)	Elasticity		Coef	(t-stat)		
Intercept	-61.670***	(-9.84)			-0.161***	(-6.886)		
Q1	-7.279***	(-3.56)			0.029***	(2.838)		
Q2	-1.985	(-1.01)			0.014	(1.497)		
Q4	-5.438***	(-2.78)			-0.010	(-0.978)		
Steer price	1.003***	(12.02)	0.745(sr)	2.246(lr)	0.807***	(8.544)	0.599(sr)	1.609(lr)
feed price	-0.190***	(-7.24)	-0.191(sr)	-0.576(lr)	-1.599***	(-5.804)	-0.111(sr)	-0.298(lr)
trend	0.432***	(10.91)			0.001***	(6.760)		
LDV	0.668***	(16.44)			0.627***	(10.635)		
sample	1990:1-2014:4				1990:1-2014:4			
Adj R^2	0.957				0.937			
Durbin-h	-0.719				2.328			

Table A12.1 Elasticity comparison (feeder to fed price linkage)

	Canada		U.S.			
	This study	Cranfield	This study		Cranfield	
cow price	0.667		0.087	0.34		
feeder calf price	-0.68		-0.175	-0.681	-0.448(sr)	-0.891 (lr)

Canada					U.S.			
	This study		Cranfield		This study		Cranfield	
Steer price	0.745(sr)	2.246(lr)	0.07(sr)	0.289(lr)	0.599(sr)	1.609(lr)	0.013(sr)	0.032(lr)
feed price	-0.191(sr)	-0.576(lr)	0.139(sr)	0.1570(sr)	-0.111(sr)	-0.298(lr)	-0.104(sr)	-0.404 (lr)

In both versions of the feeder-calf price linkage equation, the coefficient on the price of feed and the lagged dependent variable are significant at the one per cent level. The long price transmission elasticities are considerably larger than Cranfield's estimates, and we are unable to speculate why this difference occurs.

BEEF EXPORT EQUATIONS

In order to capture the relationship between beef trade and export marketing activities, two equations are estimated for imports of Canadian beef exports by the U.S. and the rest of the world. The first equation reflects beef exports between Canada and the U.S., while the second reflects beef exports from Canada to the rest of the world. We are following a different approach than Cranfield did. He estimated net trade equations (i.e. exports minus imports). We believe the inclusion of imports in the net trade equations confounds the relationships, especially with respect to export promotion by the BIC and CBEF. These export demand equations with respect to the U.S. and rest of the world are specified, respectively, as follows:

$$
\begin{aligned}
Xbf\,34 = {} & \boldsymbol{\alpha}5 + \boldsymbol{\beta}_{251}Q_1 + \boldsymbol{\beta}_{252}Q_2 + \boldsymbol{\beta}_{253}Q_4 + \boldsymbol{\beta}_{254}((RPB3/ER(-4))/(RPB4(-4) + \boldsymbol{\beta}_{225}BIC(us) \\
& + \boldsymbol{\beta}_{256}BIC(us)^2 + \boldsymbol{\beta}_{257}trend + \boldsymbol{\beta}_{258}disposable\ income + \boldsymbol{\beta}_{259}US\ imports\ \ from\ ROW \\
& + \boldsymbol{\beta}_{2510}Dummy_{bse} + \boldsymbol{\beta}_{2511}LDV
\end{aligned}
$$

$$
\begin{aligned}
Xbf\,39 = {} & \boldsymbol{\alpha}5 + \boldsymbol{\beta}_{261}Q_1 + \boldsymbol{\beta}_{262}Q_2 + \boldsymbol{\beta}_{263}Q_4 + \boldsymbol{\beta}_{264}(RPB3/(Aus\,\mathrm{Pr}\,ice) + \boldsymbol{\beta}_{265}\,1/CBEF\,\mathrm{exp} \\
& + \boldsymbol{\beta}_{266}trend + \boldsymbol{\beta}_{267}Dummy_{bse} + \boldsymbol{\beta}_{268}LDV
\end{aligned}
$$

Xbf34 is exports of beef from Canada to the U.S., RPB3 is the retail price of beef in Canada RPB4 is the retail price of beef in the U.S.., *BIC(us)* is the BIC's U.S. market real development program expenditures, (this term enters linearly and as a quadratic). US disposable income is included as an explanatory variable. U.S. imports by the rest of the world is included to account for meat that is drawn into the U.S. when U.S. off-shore exports grow.

Xbf39 is exports of beef from Canada to the rest of the world. $CBEF\,\mathrm{exp}$ is the CBEF's market development expenditures in the rest of the world which enters into this import demand equation as a reciprocal. Rather than including dummy variables for individual imports that closed their borders to Canadian beef at different points in time, we have abandoned using a BSE dummy after trying a number of combinations. The relative price of Canadian beef enters the regression as the ratio of Canadian beef prices to the Australian export price to Japan.

Regression diagnostics suggest that the equation for beef exports to the U.S. fits the data well. The equation for beef exports to the rest of the world, however, is estimated with less precision. Nevertheless, in both cases, the signs on the coefficients on price indicate that as price rises in Canada beef exports would fall (the notion here is that the higher relative beef price of Canadian beef puts Canadian exporters in a less advantageous position), while an increase in the price in the export market would result in higher net beef exports from Canada. The coefficient on relative price of Canadian beef to Australian beef is only significant at the 28 percentile level. Although it is not significant we have retained it in the regression equation.

Table A.13. OLS estimates of the net beef export equations for Canada

	Beef exports to U.S.				Beef exports to row			
Variable	Coef	(t-stat)	Elasticity		Coef	(t-stat)		
Intercept	-5988.670	(-0.151)			11802.2*	(1.973)		
Q1	-2670.200	(-0.980)			-547.314	(-0.350)		
Q2	-1463.760	(-0.533)			-425.218	(-0.299)		
Q4	-1269.510	(-0.426)			-324.377	(-0.221)		
Cdn/US price ratio(-4)	-92954.000***	(-4.139)	-1.119	0.000				
Cdn/Aus price					-4670.55	(-1.111)	-0.296	-0.420
BIC(us)exp	0.036	(1.131)	0.096	0.134				
BIC(us)exp^2	-0.025	(-0.774)	-0.058	-0.081				
1/(CBEX exp)					-2.88E+09	(-1.153)	4.75E-12	6.83E-12
trend	-440.546*	(-1.783)			47.5627	(1.071)		
income	7.880***	(3.085)	1.847	6.521				
US imports ROW	0.018	(1.314)						
dummy BSE	-65430.000***	(-6.542)						
LDV	0.283***	(3.509)			0.305**	(2.002)		
sample	1990:1-2014:4				1990:1-2014:4			
Adj R^2	0.816076				0.2945			
Durbin-h	2.562				1.666			

SR - short run elasticity and LR – long run elasticity
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Moreover, the coefficients on the BIC(us) and CBEX_exp variables have the expected sign. Although neither variable is significant at the 10% level neither variable can be dismissed as economically meaningless.

These results indicate that net beef exports to the U.S. and the rest of the world increase with investment in Canadian beef marketing activities in these regions. The elasticity of net beef exports to the U.S. with respect to BIC(us) is inelastic in the short and long run, while the elasticity of net beef exports to the rest of the world is elastic in both the short and long run.

MARKET CLEARING IDENTITIES

The equations estimated above form the main component of the simulation model and reflect the underlying behaviour of producers, processors and consumers. However, to properly close the model, force markets to clear and solve for market clearing prices the following identities are necessary:

Aggregate beef disappearance in Canada:

$$DBF3 \equiv PCBD3 \cdot POP3/1000$$

Beef production in Canada:

$$QBF3 \equiv SH3 \cdot CWSH3 + CB3 \cdot CWC3$$

Retail market clearing in Canada:

$$DBF3 \equiv QB3 + stocks_{t-1} + MBF34 + MBF39 - Xbf34 - Xbf39$$

Slaughter steer and heifer market clearing in Canada:

$$MSH3 \equiv SH3 - XSH34$$

Slaughter cow and bull market clearing in Canada:

$$MCB3 \equiv CS3 - XCB34$$

Aggregate beef disappearance in U.S:

$$DBF4 \equiv PCBD4 \cdot POP4/1000$$

Beef production in U.S.:

$$QBF4 \equiv (SH4 + XSH34) \cdot CWSH3 + (CB4 + XCB34) \cdot CWC3$$

Retail market clearing in U.S.:

$$DBF4 \equiv QB4 + stocks_{t-1} + Xbf34 - Xbf43 + NT4BF9$$

Appendix 2: Data Sources

(i) Canada

PCBD3 is quarterly Canadian per capita disappearance of beef (kilograms per person per quarter, on a carcass-weight basis). Calculated as beef disappearance divided by the Canadian population. Source: author's calculation.

DBF3 is beef disappearance. Calculated as commercial beef production (i.e., federally and provincially inspected slaughter) plus uninspected beef production minus beef exports plus beef imports plus the change in beef stocks. Source: author's calculation.

RPB3 is the deflated retail price of beef ($/lb), weighted average of the price of six retail cuts (sirloin steak, round steak, prime rib roast, blade roast stewing beef and ground beef) from fed and non-fed cattle deflated with the all-item CPI (2002=100). Source: Agriculture and Agri-food Canada; Statistics Canada (CANSIM)

RPPK3 is CPI for retail pork prices that has been deflated by the general price index (CPI), Source: Statistics Canada (CANSIM)

RPCK3 is CPI for retail pork prices that has been deflated by the general price index (CPI), Source: Statistics Canada (CANSIM)

PDY3 is deflated per capita disposable expenditure ($/ person). Source: Statistics Canada (CANSIM)

BIC_exp is calculated as BIC expenditure on Canadian marketing activities divided by the population of Canada and deflated with the all-item CPI (2002=100). Source: BIC quarterly progress reports, quarterly stakeholder reports and annual reports

SHS3 is commercial (i.e., federally and provincially inspected slaughter) of steers and heifers in Canada. Source: Livestock Meat Report and Livestock and Meat Trade Report, Agricultural and Agri-food Canada.

CBS3 is commercial (i.e., federally and provincially inspected) slaughter of cows and bulls. Source: Livestock Meat Report and Livestock and Meat Trade Report, Agricultural and Agri-food Canada.

PSS3 is the Alberta price of slaughter steer. Source: Livestock Meat Report and Livestock and Meat Trade Report, Agricultural and Agri-food Canada.

PC3 the price of Canadian slaughter cows. Source: Livestock Meat Report and Livestock and Meat Trade Report, Agricultural and Agri-food Canada.

SH3 is supply of slaughter steers and heifers, equal to commercial slaughter of steers and heifers plus exports of slaughter steers and heifers minus imports of slaughter steers and heifers. Source: author's calculation

FP3 is price of feed barley ($/tonne). Source: Market Analysis Division, Winnipeg AAFC and Source: CANFAX.

IBW3 is the inventory of beef cows in Canada on July 1. Source: Statistics Canada (CANSIM)

BCRC investment in beef cattle research in Canada, Source: BCRC staff

CB3 is supply of cows and bulls for slaughter in Canada, equal to commercial slaughter of cows and bull plus exports of slaughter cows and bulls minus imports of slaughter cows and bulls. Source: author's calculation

PFC3 is the deflated price of 500-pound feeder calves in Alberta. Source: CANFAX

CWS3 is the carcass weight of slaughtered steers (pounds). Source: author's calculations

CWc3 is the carcass weight of slaughtered cows (pounds). Source: author's calculations

Xbf34 is exports of beef from Canada to the U.S., source: calculated as imports of beef in US from Canada USDA FAS; USDA ERS

BIC(us) is BIC investment in the U.S. market development program. Source: BIC quarterly progress reports, quarterly stakeholder reports and annual reports

Xbf34 exports of beef from Canada to the rest of the world, calculated as total beef exports less exports of beef to the U.S. Source: author's calculation - Statistics Canada (Trade Analyzer) and USDA FAS.

CBEF_exp is CBEF investment in marketing activities. Source: CBEF annual reports.

POP3 is the population of Canada. Source: Statistics Canada (CANSIM)

ER is the Canada - US exchange rate in Canadian $/ US $(Statistics Canada spot rate data)

(ii) US

PCBD4 is the per capita disappearance of beef and veal - carcass weight basis (pounds) (USDA Economic Research Service). Population data was obtained from the U.S. Bureau of Economic Analysis (mid-period)

PCDY4 is the disposable personal income in the U.S. ($ per person) (U.S. Bureau of Economic Analysis)
RPB3 is the retail price of beef (U.S. $/pound) (USDA Economic Research Service)

RPPK3 is the retail price of pork (U.S. cents/pound) (USDA Economic Research Service)

RPCK3 is the average retail price of fresh whole chicken (453.6 gm) (U.S. $/pound) (US Department of Labour)

SHS4 is the commercial slaughter of steers and heifers ('000) head (USDA Economic Research Service)

CBS4 is the commercial slaughter of cows and bulls (‘000) head (USDA Economic Research Service)

SH4 is the supply of slaughter steers and heifers, calculated as commercial steer and heifer slaughter plus net exports of slaughter steers from Canada to U.S.

PS4 is the price of slaughter steers (Choice Number 2-4 Source Nebraska direct/Nebraska Steers 65-80 percent Choice $/pound) (USDA Economic Research Service)

PC4 is the price of slaughter cows (i.e. boning utility cows, Sioux Falls /cutter cows, National L.E., $/pound) (USDA Economic Research Service)

PFC4 is the price of feeder calves ($/pound) (feeder steer price, Med. No. 1, Oklahoma City, 500-550 lb) (USDA Economic Research Service)

FP4 is the price of feed corn (No. 2 yellow corn price in Central Illinois for U.S.) ($/bushel) (USDA Economic Research Service)

CWS4 is the average carcass weight for steers (pounds) (Federally inspected average dressed) (USDA Economic Research Service)

CWC4 is the average carcass weight for cows (pounds) (Federally inspected average dressed) (USDA Economic Research Service)

IBC4 is the inventory of beef cows (‘000 head) (USDA National Agricultural Statistics Service)

IDC4 is the inventory of dairy cows (‘000 head) (USDA National Agricultural Statistics Service)

WK4 is the prime bank interest rate % (US Board of Governors of the Federal Reserve System)

WL4 is the quarterly wage rate in meat packing and processing plants, 1980-1996 SIC 2011 meat packing plants 1997-2014 NAIC 3116 meat slaughtering and processing) $/quarter, US Census of manufacturers and annual survey of manufacturers (US Census Bureau)

CPI4 is the consumer price index-All urban consumers 1982-84= 100 (US Department of Labor)

$STOCKS_4$ are the frozen beef stocks in cold storage, beginning of period (million pounds) (USDA Economic Research Service)