Catalogue no. 21-601-M — No. 91
ISSN 1707-0368
ISBN 978-1-100-11350-0

Research Paper

Agriculture and Rural Working Paper Series

Price Transmission Along the Canadian Beef Supply Chain and the Impact of BSE

by Bishnu Saha and Verna Mitura

Agriculture Division
Jean Talon Building,
12th floor, 170 Tunney's Pasture Driveway
Ottawa, Ontario K1A 0T6

Telephone: 1-800-465-1991

Statistics Canada Statistique Canada

Canada

Statistics Canada
Agriculture Division

Agriculture and Rural Working Paper Series

Price Transmission Along the Canadian Beef Supply Chain and the Impact of BSE

1995-2006

December 2008

Catalogue No. 21-601-M – No. 91

ISSN 1707-0368

ISBN 978-1-100-11350-0

Frequency: Occasional

Ottawa

La version française est disponible sur demande (n^{o} 21-601-M – No. 91 au catalogue)

Published by authority of the Minister responsible for Statistics Canada.

Symbols

The following standard symbols are used in Statistics Canada publications:

.	not available for any reference period
..	not available for a specific reference period
…	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
A	excellent
B	very good
C	good
D	acceptable
^{E}	use with caution
F	too unreliable to be published

Abstract

This study investigates the dynamics of price transmission between the Canadian beef markets along the supply chain and the impact of bovine spongiform encephalopathy (BSE) on prices. Retail price models are estimated for the provinces accounting for the major share of national demand, while farm price models are estimated for the beef cattle producing provinces. A model for the processing level is also estimated with national industrial prices of beef and provincial farm prices of beef cattle.

The results indicate that retail beef prices in the major consuming provinces adjust either faster or at a greater magnitude to increases in industrial prices than to decreases. Furthermore, industrial prices adjust faster and at a greater magnitude in response to rising farm prices of beef cattle in Ontario and Quebec than when they fall. The impact of BSE on retail prices has been small and negative for Alberta and Ontario, and positive for Quebec and British Columbia. The impact of BSE on industrial prices has also been small and positive. On the contrary, strong and sustained negative influence of BSE on farm prices is evident in the results for the beef cattle producing provinces.

1.0 Introduction

The structure of the Canadian beef supply chain is changing with business consolidation occurring along the entire chain, especially at the processing and the retail levels. Concerns are often being raised about the consequences of these consolidations, especially asymmetric adjustments of prices and widening of their margins, as the processors and the retailers tend to be in a position to influence the market outcomes. Such concerns received widespread attention in Canada during the BSE[1] crisis in 2003/04 as retail beef prices bounced back to the pre-BSE level following a transitory and small initial shock, although farm prices of beef cattle declined sharply and remained significantly below the pre-BSE level. The possibility of non-competitive behaviour of the retailers and the processors came to the forefront because of this asymmetric adjustment of prices.

The Competition Bureau of Canada took an initiative to determine if any conduct contrary to the *Competition Act* affected industry pricing during the BSE crisis. A number of studies emerged as the outcome of this initiative. In a study of the pre and post BSE markets, Love (2005) argues that post-BSE prices of live cattle were affected by the U.S. import ban (reduction in demand) as well as by market power. He concludes that modest market power at multiple stages in the supply chain might have compounded the effect on farm prices. In another study of the Canadian and U.S. beef markets, Bessler (2005) notes that Canadian cattle and beef prices were influenced by cattle futures contracts in the Chicago Mercantile Exchange. He concludes that beef prices did not respond as drastically as cattle prices to the border closure due to BSE. From these two studies, the Competition Bureau found "no evidence of any communication among packers to coordinate reductions in prices" and concluded that the findings did not "indicate market conduct and pricing that suggest collusion" (Competition Bureau Canada, 2005a).

Lloyd *et al*. (2006) studied the impact of BSE in the United Kingdom (U.K.) on the spread between retail and farm prices. They report that the impact of the BSE crisis on farm prices was almost three times compared to that on retail prices. They also argue that market power in the U.K. food sector was a source of variations in price spread between the retail and farm sectors.

All these studies employed national data in their analyses and did not study the dynamics of adjustment of prices. In most cases, the retail and farm level markets are studied. However, it is important to note that the dynamics of price adjustments are regional or provincial phenomena and the analysis may not be complete if the processed product market is excluded. Hence, the dynamics of price transmission in the markets along the Canadian beef supply chain and the impact of BSE on beef and cattle prices warrant further investigation.

1. BSE is the abbreviation for Bovine Spongiform Encephalopathy (BSE), which is a neurodegenerative brain disease of cattle transmissible to human beings (WHO, 2006). The disease has an incubation period of four to five years, but is fatal for cattle within weeks to months of its onset. BSE first came to world attention in 1986 as it was diagnosed as a new form of the disease in cattle in the United Kingdom. Since then, BSE has been found in 23 countries worldwide (CFIA, 2006).

In this paper, we explore the dynamics of adjustment between the changes in retail and industrial prices of beef and between the changes in industrial prices of beef and farm prices of beef cattle. We also estimate the impacts of BSE and the relevant market factors on beef prices at the retail, the industrial and the farm levels of the markets. To the best of our knowledge, no study on this subject involving the Canadian beef sector at the provincial level has so far been reported in the literature.

The paper is organized into eight sections. Section 2 provides an overview of the concept of price transmission and the impact of BSE on prices. A theoretical analysis of the markets and prices is presented in Section 3, while the empirical models are outlined in Section 4. Section 5 presents a discussion of the data, and Section 6 outlines the estimation framework. The empirical results are reported and discussed in Section 7 and the final section provides some concluding remarks.

2.0 Price transmission and BSE

In competitive markets, increases or decreases in input prices are likely to be transmitted as proportionate changes in marginal costs and thus prices. These changes are expected to be symmetric and reversible. However, it is often noticed, especially in the retail markets, that output prices are more sensitive to a rise in input prices than to a fall. Asymmetry in price transmission refers to a situation where changes in output prices differ in terms of magnitude and/or speed of adjustments in response to increases and decreases in input prices.

Results of empirical research suggest three types of asymmetries in price transmission in the agri-food supply chains: (i) short-term asymmetries in *magnitude of transmission* of farm prices to the processing level, and processing prices to the retail level; (ii) short-term asymmetries in the *speed of adjustment* between prices at various levels; and (iii) asymmetry in adjustment of downstream prices to the notional long-run equilibrium as manifested in the variation of the speed of adjustment of the relevant price series to positive and negative deviations from its long-run equilibrium. While asymmetric transmission of prices in the agri-food supply chain has been reported in a number of studies, explanations about the causes of asymmetry have remained tentative and often debated. Among the reported causal factors, the presence of market power has been discussed the most in the literature, followed by adjustment costs (Kinnucan and Forker, 1987).

Market power in the forms of oligopoly and oligopsony may contribute to asymmetric adjustments of prices in the markets for agri-food products. Adjustment costs at the retail and processing levels are also referred to as causes of asymmetry in price transmission. However, the arguments for a faster and/or more complete adjustment of output prices in response to increases in input prices compared to decreases can be debated on theoretical grounds (Peltzman, 2000). In addition, market factors and exogenous shocks may also influence the prices along the supply chain of agri-food products that may lead to asymmetric adjustments (Goodwin and Holt, 1999).

The impact of BSE on the Canadian beef markets can be described theoretically as a shock to the retail demand as well as to farm supply. Consumer concerns about food safety issues relating to BSE may have affected the retail demand, and thus have influenced the market outcomes. Prior to 2003, the impact of the disease, if any, is likely to be revealed more as a shock on retail demand as the media coverage on BSE focused mainly on food safety issues. In May 2003, the largest importer of Canadian cattle, the United States, imposed a complete ban on imports of live cattle and beef from Canada. The border reopened in September 2003 for specific meat products from animals under 30 months of age. For live animals, the border remained closed until July 2005 when it partially reopened only for live cattle under 30 months of age. The long embargo on exports resulted in a large rise in the inventory of beef cattle in Canada and a consequent increase in domestic supply. Thus, the disease may have affected the supply side of the beef markets as well.

The impact of supply shock due to BSE is evident in the fact that farm prices of beef cattle plummeted in May through July 2003, recovered slightly in August 2003, and then settled into a price range at a much lower level than the pre-BSE period. Wholesale prices of beef, as revealed in the movements of the industrial price index, were also affected by BSE, but to a lesser extent compared to farm prices. Retail beef prices, on the other hand, registered a small initial decline in May through August 2003, but recovered within a short period. Apparently, retail prices did not respond to the post-BSE changes in industrial prices. These price movements provide an indication of asymmetric adjustments of prices between the retail, the industrial and the farm levels of the markets.

3.0 Markets and prices: A theoretical analysis

The beef and beef cattle markets in Canada are linked vertically along the supply chain and horizontally across provinces. Prices are transmitted either symmetrically or asymmetrically between these markets. While proper functioning of the markets is often linked to symmetric price transmission, importance is generally attached to asymmetries in price transmission as they reflect non-competitive market outcomes. The analyses in this section will focus on vertical price linkages along the supply chain of Canadian beef.

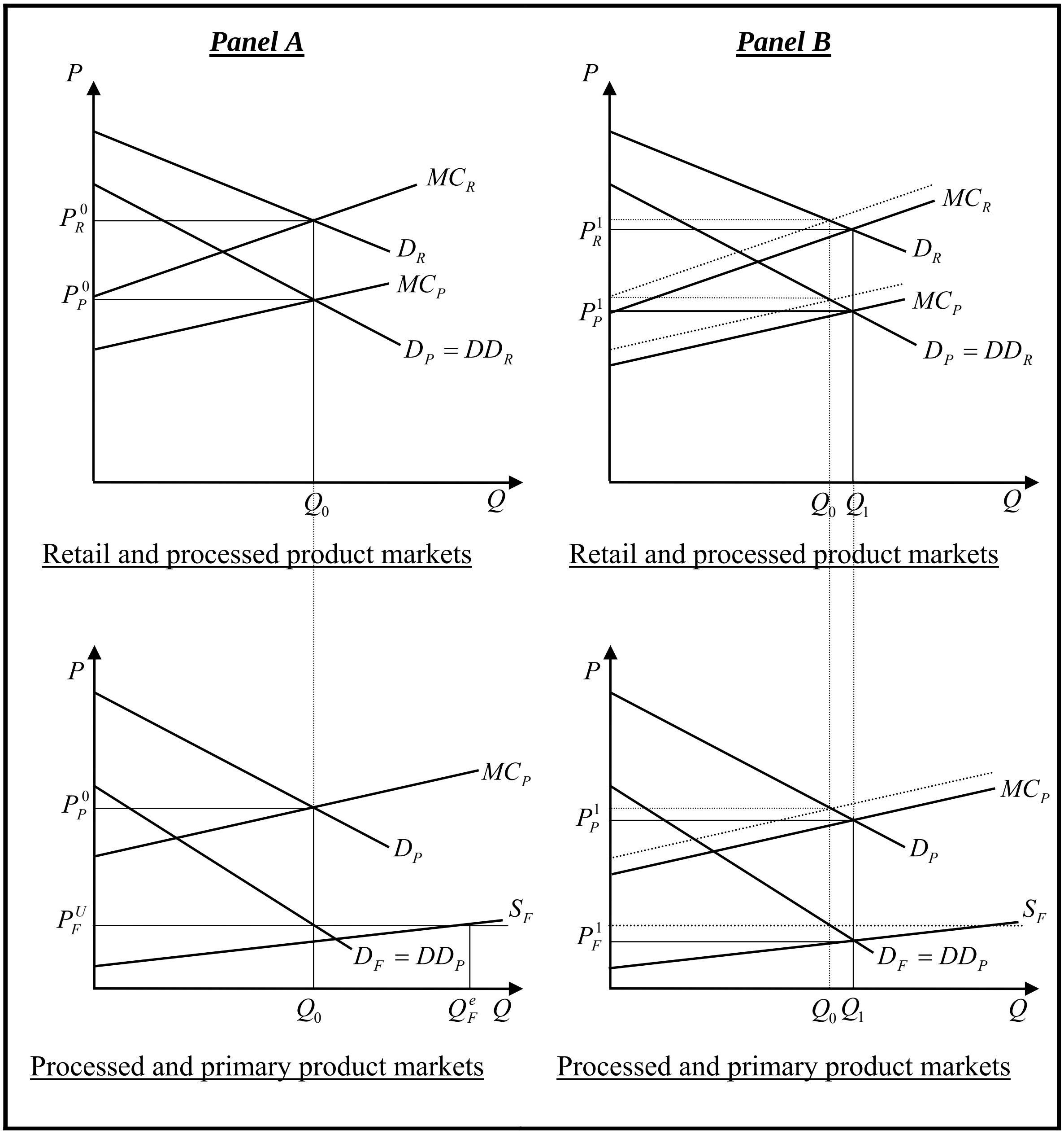
Three levels of markets are identified along the supply chain of beef: (i) the retail market for beef, (ii) the industrial market for beef, and (iii) the primary market for beef cattle. These markets are linked sequentially as the demand functions at the industrial and the primary markets are derived from the retail demand function, and the supply of beef cattle affects the marginal cost functions at the processing and retail levels. Prices at all three levels of the markets are assumed to result from the interactions of demand and supply in the relevant market. Market prices may also be affected by the structure of domestic markets and international trade at one or more levels of the markets. Changing level of concentration of the industry, especially at the retail and the processing levels, may induce collusive behaviour leading to asymmetric adjustment of prices. Changes in international trade may affect domestic supply; therefore, price adjustments are not expected to be asymmetric as long as the markets are competitive.

The linkages between the markets along the supply chain of beef and the equilibrium prices at different levels are depicted as two-dimensional expositions of supply and demand (Figure 1). The diagrams are based on the following general assumptions: (i) product homogeneity, (ii) constant proportion technology, (iii) less than a perfectly elastic supply of inputs required for beef processing and marketing, (iv) price taking consumers, and (v) perfectly competitive markets.

In Figure 1, D_R is the retail demand function, D_P is the demand at the processing level, which is derived from the retail demand (retail demand net of marketing costs, DD_R), and D_F is the demand at the farm level, which is derived from the demand at the processing level (processors' demand net of processing costs, DD_P). MC_P and MC_R represent the marginal cost functions of the processors and the retailers, respectively, that are derived from the supply function of beef cattle. The supply at the farm level (S_F) is assumed to be equal to marginal cost. In Panel A of the figure, it is also assumed that the prices of beef cattle are determined in the international market where the Canadian producers are price-taking exporters. Prices of the processed and the retail products are determined in the domestic market. Since producers are exporters, the price of beef cattle in the international market (P_F^U) is likely to be higher than the marginal cost price (P_F^1 in Panel B). Equilibria in the markets result with an output of Q_0. The quantity of beef cattle exported to the international market is $Q_F^e - Q_0$. Domestic market prices at the retail and the processing levels settle at P_R^0 and P_P^0, respectively.

The probable impact of BSE in terms of supply shifts in the domestic markets is illustrated in Panel B. The United States is the single largest importer of Canadian beef cattle and a considerable portion of Canadian beef cattle production is exported to the U.S. markets. Hence, the U.S. import ban on Canadian cattle causes domestic supply to increase. As a result, the prices of beef cattle in the domestic market (P_F^1) fall below the prices in the international markets. Lower prices of beef cattle in the domestic markets are likely to reduce the marginal costs of the processors and the retailers (MC_P and MC_R shift down). Thus beef prices at the processing and the retail levels of the domestic markets (P_P^1 and P_R^1) are also expected to fall proportionately. The quantity that clears the domestic markets is Q_1 which is greater than Q_0. The probable demand side impact of

Figure 1
Equilibrium prices at different levels of competitive markets



BSE would be an inward movement of the retail demand function that would be transmitted in the demand at the processing and farm level markets. In such a case, the equilibrium prices would drop further. The equilibrium quantity would also decrease as a result of a demand shock.

As evident in Figure 1, the prices are likely to vary with the changes in the slopes of the functions as well as the shifts. Hence, the impact of the variables that may potentially affect the slopes and the shifts of the demand and the supply functions will be accounted for in the following analysis. The structure of the analysis is founded on two equations, one for the retail demand and the other for the farm supply, which are defined in equations (3.1) and (3.2), respectively:

$$Q = f_1(P_R, P_R^S, X) \tag{3.1}$$

$$Q = f_2(P_F, Z) \tag{3.2}$$

where P_R is the retail price of the final product, P_R^S is a vector of prices of the substitutes, *X* is the retail demand shifter, P_F is the price of the primary product, and *Z* is the farm supply shifter. The substitute prices and the shifters are assumed to be determined exogenously[2]. Two additional assumptions – constant proportion technologies and constant returns to scale – are made to keep algebra manageable[3].

Assuming linear relationships between the variables, the retail demand function can be written in inverse form as:

$$P_R = a_0 - a_1 Q + a_2 P_R^S + a_3 X + \mu_R \tag{3.3}$$

Assuming similar cost structure for all farms and linear relationships between the variables, the inverse supply function of the primary product can be written as:

$$P_F = b_0 + b_1 Q + b_2 Z + \mu_F \tag{3.4}$$

where μ_R and μ_F are the relevant random errors that are assumed to be distributed normally.

Let $C_R = f_3(Q, W_R)$ and $C_P = f_4(Q, W_P)$ represent the cost functions for product transformation at the retail and the processing levels, where W_R is a vector of retail wages and energy prices, and W_P is a vector of food-manufacturing wages and energy prices, which are assumed to be exogenous. These costs are assumed to be identical for the firms in the relevant industry and linear, such that the marginal costs of marketing retail products and processing primary product are $MC_R = c_1 + c_2 W_R + \mu_R^{MC}$ and $MC_P = m_1 + m_2 W_P + \mu_P^{MC}$, respectively. Hence, the derived demand and the supply function of the processed product are given by

$$DD_R = a_0 - c_1 - a_1 Q + a_2 P_R^S + a_3 X - c_2 W_R + \nu_R \tag{3.5}$$

$$P_P = b_0 + m_1 + b_1 Q + b_2 Z + m_2 W_P + \nu_P \tag{3.6}$$

---

2. The price of the primary product may also be exogenous (i.e., determined in the North American market) especially for commodities with substantive trade volumes.

3. Most previous studies in this domain relied on these assumptions. However, these assumptions can be validated with appropriate transformation of data, such as using standard ratios of product transformation and logarithmic transformation of the variables.

Assuming a joint normal distribution of errors, the competitive market outcomes in terms of profit maximizing prices can be solved from the above equations as follows:

$$P_F = \frac{k + b_1(a_2 P_R^S + a_3 X - m_2 W_P - c_2 W_R) + a_1 b_2 Z}{a_1 + b_1}, \qquad (3.7)$$

where $k = (a_1 + b_1)(b_0) + b_1 k$.

$$P_P = P_F + m_1 + m_2 W_P \qquad (3.8)$$

$$P_R = P_P + c_1 + c_2 W_R \qquad (3.9)$$

As evident in equation (3.8), processing price is equal to farm price plus the marginal cost of processing the primary product in competitive markets. Similarly, equation (3.9) shows that retail price is comprised of processing price and the marginal cost of marketing when the markets are competitive[4].

The above analyses reveal that as long as the markets are competitive, the impact of a supply shock on farm prices is likely to be transmitted proportionately to the processing and the retail levels. Similarly, the effect of a demand shock on retail prices is also expected to be transmitted proportionately from the retail to the processing and the farm levels. However, the markets did not behave in the expected fashion during the BSE crisis. It appears from the data that farm prices dropped sharply and recovered very little, industrial prices were affected to a lesser extent, and retail prices recovered after a short period of initial shock. This brings the issue of probable market imperfection to the forefront. It is often argued that higher concentration may induce the relevant agents to exercise market power at different levels of markets along the supply chain. Market power in the form of oligopoly or oligopsony may affect prices, and thus, contribute to asymmetric price responses[5].

4.0 Modelling asymmetry in price transmission

In this section, prices in two levels of the markets are considered for simplicity. The retail price in period *t* is denoted by P_t^R and the farm level price is denoted by P_t^F . In addition, it is assumed that P_t^R is the output price, which is dependent on the input price P_t^F in time period *t*. Assuming symmetric and linear price adjustment, the following simple equation can be used to define price transmission in its simplest form:

$$P_t^R = \alpha + \beta P_t^F + \mu_t \qquad (4.1)$$

4. Given that the cost structure is unknown, one might argue that the marginal cost function could be non-linear in quantities. Even in such a case, the structure of the equations will not change if the estimations are carried out with log transformation of the variables. The exponent of the quantity variable will be multiplied with the elasticity, thereby keeping the structural characteristics of the equations similar.

5. The equations for prices changes with the market imperfection scenarios. Derivations with probable market imperfections are annexed in Appendix A.

Estimation of asymmetric adjustment has been traditionally carried out in the broader sense of irreversibility. In the context of price transmission, equation (4.1) can be written in an irreversible form as follows:

$$P_t^R = \alpha + \beta^+ D^+ P_t^F + \beta^- D^- P_t^F + \mu_t \tag{4.2}$$

where D^+ and D^- are dummy variables with $D^+ = 1$ if $P_t^F \geq P_{t-1}^F$ and $D^+ = 0$ otherwise; $D^- = 1$ if $P_t^F < P_{t-1}^F$ and $D^- = 0$ otherwise. Using these dummy variables, input (farm) price is essentially split into two variables: one for the increasing and the other for the decreasing phases of input prices. Consequently, two input price adjustment coefficients are estimated instead of one as in equation (4.1). These are β^+ for the increasing phases and β^- for the decreasing phases of input prices. If β^+ and β^- are significantly different, asymmetric adjustment is inferred.

Following a number of developments in irreversible equation modelling, Houck (1977) proposed a model that included first differences of the increasing and decreasing phases of the explanatory variables. Ward (1982) extended Houck's model by including lags of both positive and negative phases of the explanatory variable as follows:

$$\Delta P_t^R = \alpha + \sum_{j=1}^{m} \beta_j^+ D^+ \Delta P_{t-j+1}^F + \sum_{j=1}^{n} \beta_j^- D^- \Delta P_{t-j+1}^F + \upsilon_t \tag{4.3}$$

where Δ is the first-difference operator; $D^+ = 1$ if $\Delta P_{t-j+1}^F > 0$ and $D^+ = 0$ otherwise; $D^- = 1$ if $\Delta P_{t-j+1}^F < 0$ and $D^- = 0$ otherwise. The lag-lengths *m* and *n* are different as equal lag-lengths for the increasing and decreasing phases of P_t^F cannot be expected *a priori*.

Engle and Granger (1987) developed an Error Correction Model (ECM) from the Vector Auto-Regression (VAR) representation of the cointegrating relationship. In this approach, first the cointegrating relationship based on equation (4.1) is estimated. In the event of cointegration, a Vector Error Correction Model (VECM) is estimated with the lagged cointegrating residuals μ_{t-1}, which is represented by the lagged error correction terms (ECT_{t-1}) in equation (4.4). A significant estimate of the parameter in ECT_{t-1} with a value of $0 > \theta > -1$ validates the cointegrating relationship between the variables. In addition, lagged values of the dependent variable are included to account for the conditional distribution (Greene, 2003):

$$\Delta P_t^R = \alpha + \sum_{j=1}^{m} \lambda_j \Delta P_{t-j}^R + \sum_{j=1}^{m} \beta_j \Delta P_{t-j+1}^F + \theta\, ECT_{t-1} + \varepsilon_t \tag{4.4}$$

The VECM was later modified to test for asymmetric price transmission between cointegrated price series by Granger and Lee (1989). In an Asymmetric Error Correction

Model (AECM), the lagged cointegrating residuals are split into positive and negative error correction terms (ECT_{t-1}^{+} and ECT_{t-1}^{-}), representing positive and negative divergences, respectively, from the long-run equilibrium. The AECM is formulated with these error correction terms as follows:

$$\Delta P_t^R = \alpha + \sum_{j=1}^{m} \lambda_j \Delta P_{t-j}^R + \sum_{j=1}^{m} \beta_j \Delta P_{t-j+1}^F + \theta^+ ECT_{t-1}^+ + \theta^- ECT_{t-1}^- + \varepsilon_t \qquad (4.5)$$

Asymmetry in adjustment of the output price series towards its long-run equilibrium is estimated by testing the equality of the parameters in these two error correction terms.

Since equation (4.5) is based on the relationship between output and input prices, it captures only the impacts of input price changes on output price adjustments. In this study, this specification is further extended for segregating the impacts of other variables on output price. Following the derivations outlined in Section 2, potential supply and demand shifters are included in the cointegration equation. These variables are also included in equation (4.5) in their first-differenced form in order to capture their impacts on output price adjustments. In this model, lagged price differences on the right-hand side are split into positive and negative phases to estimate asymmetry in adjustment of the two prices (Rapsomanikis *et al*., 2003). With all these modifications, the specification of the AECM that has been used in the estimation of asymmetric price transmission appears as follows:

$$\begin{aligned}\Delta P_t^R = \alpha &+ \sum_{j=1}^{m} \lambda_j \Delta P_{t-j}^R + \sum_{j=1}^{m} \beta_j^+ D^+ \Delta P_{t-j+1}^F + \sum_{j=1}^{n} \beta_j^- D^- \Delta P_{t-j+1}^F \\ &+ \sum_{j=1}^{m} \gamma_j \Delta x_{t-j+1} + \theta^+ ECT_{t-1}^+ + \theta^- ECT_{t-1}^- + \varepsilon_t\end{aligned} \qquad (4.6)$$

where Δ is the first-difference operator; $D^+ = 1$ if $\Delta P_{t-j+1}^F > 0$ and $D^+ = 0$ otherwise; $D^- = 1$ if $\Delta P_{t-j+1}^F < 0$ and $D^- = 0$ otherwise; *x* is a vector of other (supply and demand shifter) variables in cointegrating relationship with the prices; and ECT_{t-1}^+ and ECT_{t-1}^- are positive and negative phases of the lagged cointegrating residuals.

In the context of equation (4.6), asymmetry occurs when positive and negative divergences from the long-run equilibrium between P_t^R and the right-hand side variables result in changes in P_t^R that differ in magnitude. This aspect of asymmetry results in unequal estimates of θ^+ and θ^-. Alternatively, in the context of two prices (i.e., prices of output and input), asymmetric transmission induces unequal lags for positive and negative changes in input price and/or significantly different estimates of β^+ and β^-.

Asymmetry in price transmission can be either positive or negative (Peltzman, 2000). In the context of two prices, 'positive asymmetry' refers to a situation in which P_t^R

responds with a higher magnitude and/or more rapidly to an increase in P_t^F than to a decrease. Alternatively, a greater and/or more rapid response of P_t^R to a decrease in P_t^F than to an increase is termed as 'negative asymmetry'. Significant estimates of positive asymmetry indicate imperfections in the market.

5.0 Data descriptions and variable transformation

The principal objective of this research is to study price transmission between retail and processed product markets, and between processed product and primary commodity markets for beef at the provincial level. The secondary objective of the study is to analyze the impacts of BSE on beef prices at the retail, processing and farm level markets. Considering the retail demand for beef, four provinces including Alberta, British Columbia, Ontario, and Quebec are selected for the analysis of retail prices. These four provinces account for more than 80% of domestic demand for beef in Canada owing to higher levels of population and per-capita disposable income.

Provincial data on industrial beef prices could not be obtained due to confidentiality reasons[6]. Therefore, the national index for industrial price of beef is used to construct an industrial prices series by taking the most recent available prices of boxed beef that are found to be the closest match of the index in terms of movements. This series has been used as the processing level prices in the estimation of the provincial models for retail prices. A single equation for industrial prices is estimated using the modified national industrial price index and the data on beef cattle prices of four provinces – Alberta, Saskatchewan, Ontario and Quebec. About 90% of the domestic packing industry's beef cattle supply comes from these four provinces. Equations for farm prices are also estimated for these four provinces. The analysis covers the period from January 1995 to December 2006.

Monthly data on retail prices are obtained from the Prices Division of Statistics Canada. Representative retail prices are constructed through the aggregation of prices recorded for individual beef cuts according to the proportion of the carcass[7] that they represent. Data on monthly producer prices are obtained from the Agriculture Division of Statistics Canada. All prices are deflated by the consumer price index (CPI) to adjust for inflation and converted to dollars per kilogram ($/kg). In order to facilitate comparison between the prices at retail and producer levels, all prices are converted to dollars per kilogram ($/kg) of carcass weight equivalents for beef using the conversion factors published by the United States Department of Agriculture (USDA). The prices are then transformed to their log values.

---

6. Statistics Canada does not undertake a comprehensive survey of beef prices at the processing level. Because of limited number of processors and price quotes, these prices are confidential.

7. Weights, Measures, and Conversion Factors for Agricultural Commodities and Their Products, USDA Agricultural Handbook Number 697, 1992.

Exogenous variables that are used in the models include per-capita disposable income as a demand shifter, retail prices of substitutes (e.g., pork and chicken) which may affect the slope of the retail demand curve for beef, and average hourly wage rates for retail grocery stores and for meat product manufacturing firms as indicators of changes in costs.

The costs of electricity and fuel are often considered as significant contributors to prices, especially at the retail and wholesale levels. With a view to account for these costs, attempts are made to include the provincial CPI for energy in the models. However, the CPI for energy is found to have no long-term relationship with the prices in any of the provincial models. In order to assess the impact of BSE, an index of media coverage is used, which is based on the count of newspaper articles per month on the topic of BSE[8]. Four major newspapers, one for each province, were searched for the articles[9].

The effect of changes in supply on prices is estimated using the quantity of beef that enters the supply chain. Provincial level monthly data on weights of slaughter cattle and calves are obtained from the Agriculture Division of Statistics Canada[10]. The data on farm prices of beef cattle in the United States are obtained from the United States Department of Agriculture. The quantity data are transformed into thousands of tonnes of carcass weight equivalent for beef. The series are also used in the empirical analysis in log form.

6.0 Estimation framework

The estimation proceeds in four steps (Figure 2). First, each time series of each variable is tested for the order of integration. The Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1979) is performed by including up to 12 lags of the differenced terms in the regression. The Weighted Symmetric test (WS) (Pantula *et al*., 1994), which is a weighted double-length regression that uses the same number of lags and leads with the weights of (t-1)/T and 1-(t-1)/T, respectively, is also performed. The appropriate lag length is chosen on the basis of the Akaike Information Criterion (AIC) by trading off parsimony against reduction in the sum of squares of the residuals. While a few of the series are found to be trend-stationary in their level form [I(0)], most of them are stationary in their first-differenced form, that is, the data series are integrated of order one [I(1)]. Since none of the series is found to be integrated of an order higher than one, the next step is to test for the cointegrating relationships between the series.

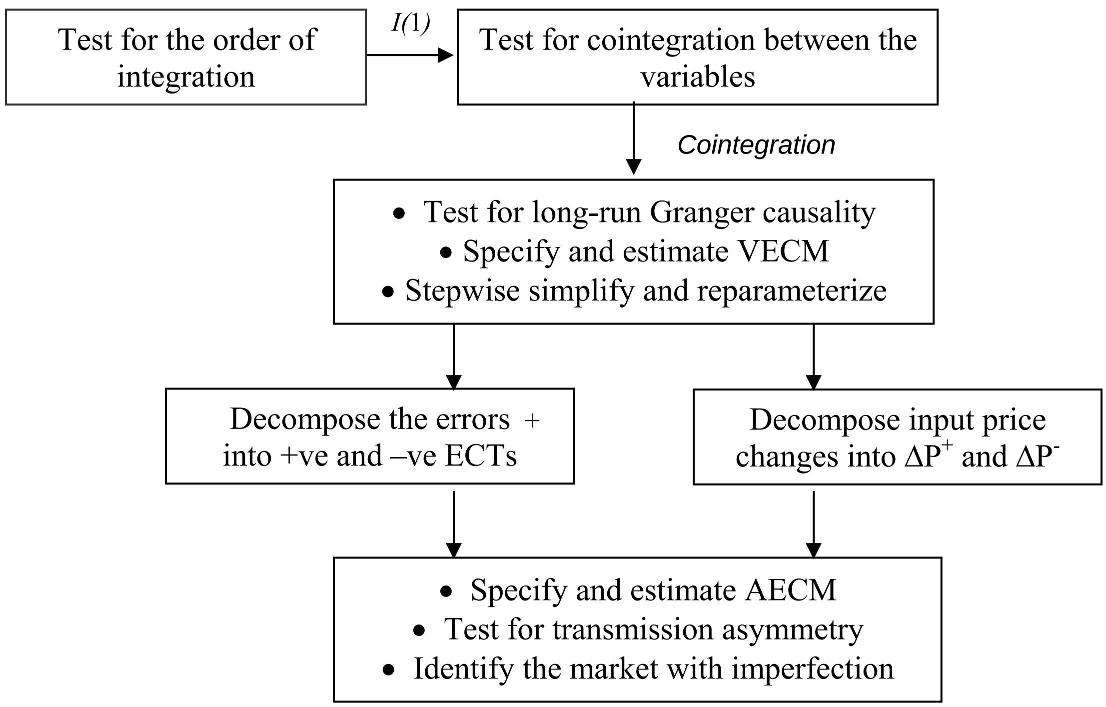
---

8. The search keywords include “BSE”, “Mad Cow” and “Bovine spongiform encephalopathy” for BSE.

9. The newspapers are the Calgary Herald for Alberta, the Vancouver Sun for British Columbia, The Globe and Mail for Ontario, and the Montreal Gazette for Quebec.

10. The data for the quantity of beef cattle that enters the supply chain are collected twice a year and monthly supply data are generated using fixed weights.

Figure 2
Estimation framework for studying asymmetric price transmission



Note: VECM = Vector Error Correction Model
ECT= Error Correction Terms
AECM = Asymmetric Error Correction Model

The time series representing the variables are grouped on the basis of the theoretical models specified in Section 2 for testing cointegrating relationships between them. The null hypothesis of no cointegration against the alternative hypothesis of at least one cointegrating vector is tested using the system approach following Johansen's procedure (Johansen 1988, 1991), and also using the single equation approach following Engle and Granger (1987).

Rejection of the null hypothesis of no cointegration is an indication that prices along with some other relevant variables move together and that the markets along the supply chain are integrated. If the null hypothesis of no cointegration is not rejected, the test is repeated with changing combinations of the variables until a cointegrating vector is found. If the test results indicate that the series representing the variables are cointegrated, the long-run causality between the prices series is tested following Granger (1969, 1988). The VECM is specified and estimated according to the direction of causality, stepwise simplified and re-parameterized.

The error correction terms (ECTs) are split into positive and negative phases. The input price (i.e., prices of processed products in the retail price equation, and farm prices in the equation for processing prices) changes are also decomposed into positive and negative phases. Finally, the AECM is estimated as per equation (4.6). The parameters in the split ECTs are tested for the null hypothesis of symmetry in adjustment towards the long-term equilibrium. The nature of price transmission and the extent of market integration are studied using the parameters in input prices.

7.0 Empirical results

The series used in this study comprise 144 monthly observations on retail and farm prices of beef (RB_t and FB_t respectively), retail prices of pork and chicken (RP_t and RC_t respectively), industrial price of beef (PB_t), quantity of beef entering the supply chain (QB_t), international export of cattle (IEC_t), provincial export of cattle (PEC_t), average hourly wage rates for meat product manufacturing and grocery stores (WM_t and WG_t respectively), disposable income per capita (YC_t), and the index of media coverage on BSE (BS_t). As mentioned earlier, retail price models are estimated for the provinces with higher demand: Alberta, British Columbia, Ontario and Quebec. Farm price models for the major beef cattle producing provinces – Alberta, Ontario, Quebec and Saskatchewan – and a national model for industrial beef prices are also estimated.

All data series are first tested for the order of integration. The results of the ADF tests are reported in Table 1. The results indicate that most of the series are non-stationary in levels and stationary in first-differenced forms. A few series including wage rates at grocery stores (WG_t) in Alberta and Ontario, wage rates for meat product manufacturing (WM_t) in Alberta and Quebec, media coverage on BSE (BS_t) in British Columbia, quantity of beef entering the supply chain (QB_t) in Saskatchewan and also in Canada are, however, found to be stationary in level form.

At the second stage, cointegration tests are conducted for each of the models to find long-term relationships between the relevant variables. Both the system approach (Johansen trace test) and the single equation approach (Engle-Granger test) are followed. The system approach is generally relied upon. However, the result of the single equation approach is examined in cases where the system approach fails to reject the null hypothesis of no cointegration in any possible combination of the variables as per the theoretical relationships[11] or a weak cointegrating relationship.

Initially, the theoretical analyses in Section 3 are followed to include in the system all the variables that are likely to affect the relevant prices and to look for at least one cointegrating relationship. In the event that the null hypothesis of no cointegration cannot be rejected, the test is repeated by different combinations of the variables until at least one cointegrating relationship is found. The Johansen trace test is used to detect the presence of at least one cointegrating vector in the system approach, while the unit root

11. In addition to the variables listed in Table 1, other variables including gasoline prices and CPIs for energy were also tried for cointegrating relationships with prices. However, the results showed no long term relationship of these variables with prices either at the retail or at the processing level.

Table 1
Augmented Dickey-Fuller test results for the data series

Province	Variable	Level Form (Lag)	First Difference Form (Lag)	Inference
Alberta	RB_t^{AB}	-2.01 (7)	-5.15** (6)	$RB_t^{AB} \sim I(1)$
	RP_t^{AB}	-2.55 (2)	-7.91** (2)	$RP_t^{AB} \sim I(1)$
	FB_t^{AB}	-1.71 (12)	-4.67** (12)	$FB_t^{AB} \sim I(1)$
	QB_t^{AB}	-2.92 (9)	-5.94** (9)	$QB_t^{AB} \sim I(1)$
	IEC_t^{AB}	-1.95 (3)	-6.68** (2)	$IEC_t^{AB} \sim I(1)$
	WG_t^{AB}	-3.81* (6)	…	$WG_t^{AB} \sim I(0)$
	WM_t^{AB}	-3.76* (2)	…	$WM_t^{AB} \sim I(0)$
	YC_t^{AB}	-3.12 (5)	-3.52* (4)	$YC_t^{AB} \sim I(1)$
	BS_t^{AB}	-2.31 (9)	-4.46** (8)	$BS_t^{AB} \sim I(1)$
British Columbia	RB_t^{BC}	-2.53 (2)	-8.33** (2)	$RB_t^{BC} \sim I(1)$
	RP_t^{BC}	-2.29 (3)	-8.84** (2)	$RP_t^{BC} \sim I(1)$
	FB_t^{BC}	-1.36 (11)	-4.91** (10)	$FB_t^{BC} \sim I(1)$
	QB_t^{BC}	-1.64 (8)	-6.58** (6)	$QB_t^{BC} \sim I(1)$
	WG_t^{BC}	-2.73 (3)	-7.45** (3)	$WG_t^{BC} \sim I(1)$
	WM_t^{BC}	-1.76 (5)	-6.66** (4)	$WM_t^{BC} \sim I(1)$
	YC_t^{BC}	-2.60 (4)	-5.66** (3)	$YC_t^{BC} \sim I(1)$
	BS_t^{BC}	-4.49** (2)	…	$BS_t^{BC} \sim I(0)$
Ontario	RB_t^{ON}	-2.53 (3)	-7.92** (2)	$RB_t^{ON} \sim I(1)$
	RP_t^{ON}	-2.69 (7)	-4.91** (5)	$RP_t^{ON} \sim I(1)$
	FB_t^{ON}	-2.32 (11)	-5.24** (9)	$FB_t^{ON} \sim I(1)$
	QB_t^{ON}	-1.14 (12)	-4.42** (12)	$QB_t^{ON} \sim I(1)$
	IEC_t^{ON}	-1.98 (2)	-6.52** (2)	$IEC_t^{ON} \sim I(1)$
	WG_t^{ON}	-3.48* (2)	…	$WG_t^{ON} \sim I(0)$
	WM_t^{ON}	-1.80 (4)	-6.86** (3)	$WM_t^{ON} \sim I(1)$
	YC_t^{ON}	-1.48 (3)	-5.69** (2)	$YC_t^{ON} \sim I(1)$
	BS_t^{ON}	-2.48 (6)	-4.46** (5)	$BS_t^{ON} \sim I(1)$

See notes at end of table.

Table 1
Augmented Dickey-Fuller test results for the data series (continued)

Province	Variable	Level Form (Lag)	First Difference Form (Lag)	Inference
Quebec	RB_t^{QC}	-3.63 (9)	-3.84* (8)	$RB_t^{QC} \sim I(1)$
	RP_t^{QC}	-2.71 (3)	-3.78* (2)	$RP_t^{QC} \sim I(1)$
	FB_t^{QC}	-1.98 (6)	-4.54** (5)	$FB_t^{QC} \sim I(1)$
	QB_t^{QC}	-2.78 (7)	-6.70** (6)	$QB_t^{QC} \sim I(1)$
	PEC_t^{QC}	-2.50 (12)	-4.72** (12)	$PEC_t^{QC} \sim I(1)$
	WG_t^{QC}	-2.51 (3)	-7.97** (3)	$WG_t^{QC} \sim I(1)$
	WM_t^{QC}	-3.72* (2)	…	$WM_t^{QC} \sim I(0)$
	YC_t^{QC}	-1.60 (4)	-5.89** (3)	$YC_t^{QC} \sim I(1)$
	BS_t^{QC}	-2.93 (10)	-3.43* (9)	$BS_t^{QC} \sim I(1)$
Saskatchewan	RP_t^{SK}	-3.39 (6)	-5.95** (4)	$RP_t^{SK} \sim I(1)$
	FB_t^{SK}	-1.55 (11)	-5.02** (10)	$FB_t^{SK} \sim I(1)$
	QB_t^{SK}	-3.79* (4)	…	$QB_t^{SK} \sim I(0)$
	IEC_t^{SK}	-2.09 (2)	-6.46** (2)	$IEC_t^{SK} \sim I(1)$
Canada and U.S.	PB_t^{CA}	-1.72 (11)	-4.97** (11)	$PB_t^{CA} \sim I(1)$
	FB_t^{US}	-1.51 (6)	-6.38** (6)	$FB_t^{US} \sim I(1)$
	QB_t^{CA}	-3.63* (6)	…	$QB_t^{CA} \sim I(0)$
	WM_t^{CA}	-2.27 (11)	-4.94** (9)	$WM_t^{CA} \sim I(1)$
	BS_t^{CA}	-2.61 (12)	-4.01** (10)	$BS_t^{CA} \sim I(1)$

Notes: The subscript *t* denotes time in months and the superscript AB stands for Alberta, BC for British Columbia, ON for Ontario, SK for Saskatchewan, QC for Quebec, CA for Canada and US for the United States. The lengths of lag for the unit root test are selected according to the Akaike Information Criterion (AIC). The ADF regressions include a constant and trend both for levels and the first differences. The superscripts * and ** denotes a 5% and 1% level of significance, respectively.

test of the errors is relied upon in the single equation approach. In both cases, a constant and a trend are assumed as deterministic factors. The number of augmenting lags in the relationship is selected on the basis of the Akaike Information Criterion (AIC). The results of the cointegration tests for the retail price models are reported in Table 2.

7.1 *Models for retail prices*

The results of the cointegration analyses for the retail price models (Table 2) suggest the presence of at least two cointegrating relationships in the models for Alberta and British Columbia, at least one in the model for Ontario, and four in the model for Quebec. The series that are found to have cointegrating relationships in the retail price models for Alberta, British Columbia and Ontario represent the relevant provincial data on retail prices of beef (RB) and pork (RP), disposable income per-capita (YC), quantity of beef entering the supply chain (QB), wage rates at grocery stores (WG) and the media count index for BSE (BS).

In the model for Quebec, cointegrating relationships between the variables fall apart if the series for per-capita disposable income is added to the system. The time series for meat product manufacturing wage rates are found not to have cointegrating relationships in any of the systems.

The cointegrating vectors in Table 2 denote the long-term relationships between the variables in the models for retail prices. The signs of the vectors are as expected except that of the quantity variable in the model for British Columbia, which is positive (sign changes when the vector is transferred to the right hand side of the equation). Out of four major consuming provinces, British Columbia has the lowest level of own quantity of beef and obtains a major portion of its supply from Alberta. Hence, the positive relationship between quantity and price may be due to a supply response of prices to increases in demand. The positive sign of the vectors for the BSE media count index is worth noting. It reflects the commonly observed fact that retail beef prices in all provinces remained relatively steady even after the beef sector was hit by BSE. However, the short-run dynamics of adjustment of prices with the index will provide more information on the impact of BSE on retail prices.

Based on the cointegrating relationships, AECMs for retail prices are estimated. In addition to the cointegrating variables, twelve monthly dummies (MDs) are used in the AECMs. The results are reported in Table 3. Two sets of parameters are important in the context of price transmission asymmetry – parameters in the error correction terms (ECTs) and the parameters in the variables for the changes in industrial prices. The speed of adjustment of retail prices towards the notional long-run equilibrium is captured by the parameters in positive and negative phases of the error correction terms $ECT^{+}(-1)$ and $ECT^{-}(-1)$. The Wald test statistics fail to reject the null hypothesis of no long-term asymmetry in all retail price models. However, the estimated parameters in the models for Quebec, Ontario and British Columbia suggest that negative deviations of retail prices from the long-run equilibrium adjust with a relatively faster speed compared to positive deviations.

The parameters in positive and negative changes in processors' prices (ΔPB^{+} and ΔPB^{-}) capture the dynamics of short-term adjustments in retail prices in response to positive and

Table 2
Cointegration test statistics for the variables in the retail price models

Province	Series	Cointegration Vector	Eigenvalue[1]	H_0	Trace	5% C.V.
Alberta	RB_t^{AB}	1.0000	0.3005	*r = 0*	169.45**	136.61
	PB_t^{CA}	-0.4417	0.2462	*r = 1*	120.85**	104.94
	RP_t^{AB}	-0.3716	0.2039	*r = 2*	82.41*	77.74
	QB_t^{AB}	0.1205	0.1476	*r = 3*	51.39	54.64
	YC_t^{AB}	-1.4672	0.1343	*r = 4*	29.66	34.55
	WG_t^{AB}	-0.1261	0.0525	*r = 5*	10.05	18.17
	BS_t^{AB}	-0.0010	0.0197	*r = 6*	2.71	3.74
British Columbia	RB_t^{BC}	1.0000	0.3799	*r = 0*	185.90**	136.61
	PB_t^{CA}	-0.0609	0.3023	*r = 1*	124.74**	104.94
	RP_t^{BC}	-0.2648	0.2418	*r = 2*	78.67*	77.74
	QB_t^{BC}	-0.0221	0.1443	*r = 3*	43.23	54.64
	YC_t^{BC}	-2.4634	0.1003	*r = 4*	23.29	34.55
	WG_t^{BC}	-0.5760	0.0597	*r = 5*	9.76	18.17
	BS_t^{BC}	-0.0043	0.0146	*r = 6*	1.88	3.74
Ontario	RB_t^{ON}	1.0000	0.3211	*r = 0*	158.17**	136.61
	PB_t^{CA}	-0.1229	0.2361	*r = 1*	108.59*	104.94
	RP_t^{ON}	-0.5180	0.1824	*r = 2*	74.12	77.74
	QB_t^{ON}	0.1489	0.1453	*r = 3*	48.34	54.64
	YC_t^{ON}	-0.7851	0.1263	*r = 4*	28.24	34.55
	WG_t^{ON}	-0.4169	0.0573	*r = 5*	10.95	18.17
	BS_t^{ON}	-0.0005	0.0262	*r = 6*	3.40	3.74
Quebec	RB_t^{QC}	1.0000	0.4998	*r = 0*	202.79**	104.94
	PB_t^{CA}	-0.0901	0.2661	*r = 1*	107.88**	77.74
	RP_t^{QC}	-0.3214	0.1547	*r = 2*	65.50**	54.64
	QB_t^{QC}	0.0611	0.1412	*r = 3*	42.48**	34.55
	WG_t^{QC}	-0.0444	0.0841	*r = 4*	21.62*	18.17
	BS_t^{QC}	-0.0002	0.0676	*r = 5*	3.58	3.74

1. The eigenvalues are sorted from the highest to the lowest.
Notes: The 5% critical values (C.V.) are taken from Osterwald-Lenum (1992). The superscripts * and ** denotes a 5% and 1% level of significance, respectively.

Table 3
Results of the estimated asymmetric error correction models for retail beef prices

Alberta		British Columbia		Ontario		Quebec	
Variable[1]	*Estimate (t-Stat)*	Variable[1]	*Estimate (t-Stat)*	Variable[1]	*Estimate (t-Stat)*	Variable[1]	*Estimate (t-Stat)*
ΔRB (-1)	0.5580 (3.54)	ΔRB (-1)	0.5037 (3.45)	ΔRB (-1)	0.1584 (1.01)	ΔRB (-1)	0.3554 (2.27)
ΔRB (-3)	-0.1381 (-1.97)	…	…	…	…	ΔRB (-3)	0.2065 (2.63)
$\Delta PB^{+}(-1)$	0.9178 (3.24)	$\Delta PB^{+}(-1)$	0.3750 (2.10)	$\Delta PB^{+}(-1)$	0.5153 (1.87)	$\Delta PB^{+}(-1)$	0.5849 (2.50)
…	…	$\Delta PB^{+}(-2)$	0.3718 (1.54)	…	…	…	…
ΔPB^{-}	0.5295 (2.86)	$\Delta PB^{-}(-1)$	0.2094 (1.87)	…	…	$\Delta PB^{-}(-1)$	0.4616 (2.78)
$\Delta PB^{-}(-2)$	0.4691 (2.14)	$\Delta PB^{-}(-2)$	0.2626 (1.71)	$\Delta PB^{-}(-2)$	0.7130 (3.41)	$\Delta PB^{-}(-2)$	0.3387 (1.94)
ΔRP	0.2174 (2.70)	ΔRP	0.3769 (6.06)	ΔRP (-1)	0.1506 (2.22)	ΔRP (-1)	0.1861 (3.27)
…	…	…	…	ΔQB (-1)	-0.0855 (-1.46)	…	…
ΔQB (-5)	-0.0712 (-2.43)	ΔQB (-4)	0.0106 (1.68)	ΔQB (-4)	-0.1284 (-2.18)	ΔQB (-3)	-0.0239 (-2.39)
…	…	ΔYC (-4)	-2.1869 (-3.60)	…	…	…	…
ΔYC (-7)	0.9519 (1.63)	ΔYC (-5)	1.4234 (2.69)	ΔYC (-5)	1.3880 (1.96)	…	…
ΔWG(-5)	-0.1100 (-1.99)	ΔWG(-4)	0.1565 (4.00)	ΔWG(-3)	0.2052 (2.28)	ΔWG(-3)	0.0591 (1.10)
ΔBS (-3)	-0.0005 (-2.24)	ΔBS (-6)	0.0009 (3.24)	ΔBS (-3)	-0.0004 (-1.37)	ΔBS (-6)	0.0010 (3.29)
$ECT^{+}(-1)$	-0.6253 (-2.93)	$ECT^{+}(-1)$	-0.7633 (-4.05)	$ECT^{+}(-1)$	-0.5559 (-2.80)	$ECT^{+}(-1)$	-0.4666 -(2.08)
$ECT^{-}(-1)$	-0.5870 (-3.06)	$ECT^{-}(-1)$	-0.8536 (-4.35)	$ECT^{-}(-1)$	-0.7237 (-3.64)	$ECT^{-}(-1)$	-0.6114 (-3.06)
MD1	0.0284 (3.83)	MD4	-0.0117 (-1.80)	MD6	0.0257 (3.16)	MD8	0.0163 (2.63)
MD2	-0.0217 (-2.87)	MD8	0.0153 (1.96)	MD11	-0.0268 (-3.48)	…	…
MD12	-0.0170 (-2.35)	…	…	…	…	…	…

1. The lag lengths are in parentheses; the absence of a lag length indicates that the variable is not lagged. The superscripts plus (+) and minus (–) denote positive and negative changes, respectively, in the variable ΔPB and the error correction term (ECT).

Note: Dependent variable: changes in retail price of beef (Δ*RB*) negative changes in processors' prices. The estimates for Alberta, Ontario and Quebec show that retail prices adjust faster in response to increases in industrial prices than to decreases. In Alberta, increases in industrial prices are transmitted to the retail level almost completely within one month; however, it takes two months for retail prices to adjust at a similar magnitude to falling industrial prices. In Ontario and Quebec, retail prices adjust partially to increasing industrial prices in one month and also partially to decreasing industrial prices in two months. In British Columbia, the magnitude of transmission of increases in industrial prices is relatively greater compared to that of decreases with no difference in adjustment lags. These indicate the presence of asymmetry in adjustment of retail prices to rising and falling industrial markets for beef.

The short-run impact of BSE on retail prices, as indicated by the estimated parameters in the BSE media count index (ΔBS), is positive for Quebec and British Columbia, and negative for Alberta and Ontario. It is important to note that beef production in Ontario and Alberta jointly account for the largest share of total national beef production and exports, while Quebec and British Columbia consume most of their respective provincial production.

Among other factors, the short-run impact of a demand shift is likely to be substantial as revealed by the estimated parameters in the changes in per-capita disposable income (ΔYC). However, the impact of changes in per-capita disposable income in British Columbia is complex as the signs of the parameters in two successive lags are different. The estimated parameters in the changes in retail prices of pork (ΔRP) as a substitute indicate significant impact of the changes in the slope of the retail demand. The significant parameters in the monthly dummies (MDs) indicate the presence of seasonality in the retail price cycles of beef that differ by province. Retail beef prices in Alberta tend to rise in January and fall in February and December. In Ontario, retail prices increase in June and decrease in November, while in British Columbia retail prices have tendencies to rise in August and fall in April. Retail prices in Quebec also tend to increase in August.

7.2 *Farm price models*

The cointegration test results for the farm price models are provided in Table 4. The results indicate the presence of at least three cointegrating vectors in the models for Quebec and at least one in the model for Ontario. In the model for Alberta, while the null hypothesis of no cointegrating relationship is strongly rejected (p-value 0.001), the null of the presence of at most one cointegrating relationship is rejected at the 9% level. However, the Engle-Granger test statistic (-6.37 at 6 lags; p-value 0.000) strongly suggests that the Alberta farm price series possesses a long-term relationship with the other variables in the model. In the model for Saskatchewan, the null of at most one cointegrating relationship is rejected at the 7% level if retail pork prices and the BSE

Table 4
Cointegration test statistics for the variables in the farm price models

Province	Series	Cointegration Vector	Eigenvalue[1]	H_0	Trace	5% C.V.
Alberta	FB_t^{AB}	1.0000	0.4225	r = 0	126.89**	104.94
	QB_t^{AB}	-0.2614	0.3369	r = 1	74.74	77.74
	IEC_t^{AB}	-0.0129	0.1690	r = 2	35.71	54.64
	FB_t^{US}	-0.8996	0.1195	r = 3	18.12	34.55
	YC_t^{AB}	-0.5325	0.0597	r = 4	6.03	18.17
	BS_t^{AB}	0.0026	0.0019	r = 5	0.18	3.74
Ontario	FB_t^{ON}	1.0000	0.4771	r = 0	162.85**	136.61
	QB_t^{ON}	0.0893	0.3329	r = 1	105.80*	104.94
	IEC_t^{ON}	-0.0189	0.3207	r = 2	70.18	77.74
	FB_t^{US}	-0.6160	0.2003	r = 3	36.16	54.64
	RP_t^{ON}	-2.7359	0.1217	r = 4	16.49	34.55
	YC_t^{ON}	-0.1628	0.0366	r = 5	5.07	18.17
	BS_t^{ON}	0.0026	0.0201	r = 6	1.78	3.74
Quebec	FB_t^{QC}	1.0000	0.4441	r = 0	249.85**	136.61
	QB_t^{QC}	0.5460	0.3855	r = 1	174.69**	104.94
	PEC_t^{QC}	-0.0473	0.3680	r = 2	112.37**	77.74
	FB_t^{US}	-0.8360	0.1962	r = 3	53.63	54.64
	RP_t^{QC}	-0.6944	0.1105	r = 4	25.68	34.55
	WM_t^{QC}	0.4511	0.0493	r = 5	10.69	18.17
	BS_t^{QC}	0.0116	0.0324	r = 6	4.21	3.74
Saskatchewan	FB_t^{SK}	1.0000	0.3768	r = 0	92.40	104.94
	QB_t^{SK}	-0.0267	0.1610	r = 1	47.48	77.74
	IEC_t^{SK}	0.0171	0.1333	r = 2	30.80	54.64
	FB_t^{AB}	-1.1444	0.0953	r = 3	17.21	34.55
	RP_t^{SK}	-0.1678	0.0518	r = 4	7.70	18.17
	BS_t^{AB}	0.0012	0.0274	r = 5	2.64	3.74

1. The eigenvalues are sorted from the highest to the lowest.

Notes: The 5% critical values (C.V.) are taken from Osterwald-Lenum (1992). The superscripts * and ** denote 5% and 1% level of significance, respectively.

media count index are taken out of the system. The Engle-Granger test statistic (-5.17 at 6 lags; p-value 0.029), however, indicates the presence of a long-run relationship between the Saskatchewan farm prices series and the other variables including retail pork prices and the BSE media count index.

The cointegrating vectors in Table 4 signify the long-term relationships between farm prices of beef cattle (FB) and other variables in the models. The signs of the vectors are as expected except that for the quantity variables (QB) in the models for Alberta and Saskatchewan, which is positive (sign changes as the vector is transferred to the right hand side of the equation). Alberta and Saskatchewan are net exporters of beef cattle, while Ontario and Quebec are net importers. Hence, the supply-side effect in Alberta and Saskatchewan is likely to be higher than the respective demand-side effect. The positive sign of the vectors for quantity in Alberta and Saskatchewan can be explained as the supply response of prices. The negative sign of the vector for the international export of beef cattle (IEC) in the Saskatchewan model can be explained in terms of opposite trends in provincial farm prices and international export quantities.

The cointegrating vectors for farm prices of beef cattle (FB) in the United States in the models for Alberta, Ontario and Quebec suggest a substantial positive long-term impact of the variable on farm prices in these provinces. However, the U.S. farm prices do not have any long-term relationship with Saskatchewan farm prices. The cointegrating vector for Alberta farm prices in the Saskatchewan model is negative suggesting a positive long-term relationship between these two provincial farm prices. On the contrary, Saskatchewan farm prices are found not to be cointegrated in the Alberta farm prices model. This supports the fact that the majority of Saskatchewan beef cattle are exported to Alberta, where the Saskatchewan producers are price-takers.

The series on meat product manufacturing wages (WM) is found to be cointegrated only in the Quebec model. The negative relationship of the variable with farm prices corroborates the theoretical analysis in Section 2. An adverse (negative) long-term impact of BSE on farm prices is revealed by the positive sign of the vectors for the BSE media count index (BS)[12].

AECMs for farm prices are estimated on the basis of the cointegrating relationships. Asymmetry in terms of the speed of adjustment of farm prices towards the notional long-run equilibrium is studied in these models. The test statistics involving the parameters in the positive and negative phases of the error correction terms $ECT^{+}(-1)$ and $ECT^{-}(-1)$ fail to reject the null hypothesis of no asymmetry in all provincial models (Table 5). However, the estimated parameters in the Saskatchewan model suggest that positive deviations of farm prices from the long-run equilibrium are adjusted at a relatively faster

12. While Quebec farm prices appears to be the hardest hit, comparison of the results may not be appropriate as they are obtained from different indices based on provincial media coverage on BSE.

Table 5
Results of the estimated asymmetric error correction models for farm prices of beef

Alberta		**Ontario**		**Quebec**		**Saskatchewan**	
Variable[1]	***Estimate (t-Stat)***	**Variable**[1]	***Estimate (t-Stat)***	**Variable**[1]	***Estimate (t-Stat)***	**Variable**[1]	***Estimate (t-Stat)***
ΔFB (-1)	0.5797 (7.96)	ΔFB (-1)	0.5853 (5.43)	ΔFB (-1)	0.6133 (3.27)	ΔFB (-1)	0.2247 (3.82)
ΔFB (-2)	-0.3996 (-6.74)	ΔFB (-2)	-0.4057 (-6.76)	ΔFB (-2)	-0.2503 (-3.27)	ΔFB (-3)	-0.2558 (-4.99)
ΔFB (-4)	0.2909 (4.53)	ΔFB (-3)	0.1227 (1.91)	ΔFB (-3)	-0.2282 (-2.75)	ΔFB (-6)	-0.2695 (-5.29)
ΔFB (-5)	-0.3858 (-6.77)	…	…	…	…	…	…
ΔQB (-1)	0.1925 (2.04)	ΔQB (-1)	-0.0302 (-1.22)	ΔQB	-0.1647 (-3.31)	ΔQB	-0.0709 (-3.66)
ΔIEC	0.0112 (4.19)	ΔIEC (-1)	0.0108 (4.13)	ΔPEC	0.0190 (1.79)	ΔIEC (-1)	-0.0136 (-4.13)
ΔFB^{US}	0.5102 (4.07)	ΔFB^{US}	0.4677 (4.20)	ΔFB^{US}	0.6935 (2.97)	…	…
ΔYC (-1)	3.1559 (2.51)	…	…	ΔFB^{US} (-4)	0.6996 (3.27)	ΔFB^{AB}	0.9021 (14.13)
ΔYC (-3)	-3.2886 (-2.41)	ΔYC (-11)	2.3353 (1.73)	ΔWM (-2)	-0.3596 (-1.65)	…	…
…	…	ΔRP (-6)	0.1496 (1.25)	ΔRP (-6)	0.3453 (1.39)	ΔRP (-10)	0.2552 (1.49)
ΔBS	-0.0025 (-3.77)	ΔBS (-2)	-0.0036 (-4.32)	ΔBS (-2)	-0.0051 (-3.63)	ΔBS^{AB} (-1)	-0.0023 (-3.16)
ΔBS (-1)	-0.0032 (-5.46)	ΔBS (-3)	-0.0016 (-1.85)	ΔBS (-3)	-0.0061 (-4.13)	…	…
ECT^{+}(-1)	-0.7153 (-4.89)	ECT^{+}(-1)	-0.6926 (-4.51)	ECT^{+}(-1)	-0.7464 (-3.52)	ECT^{+}(-1)	-0.4688 (-4.22)
ECT^{-}(-1)	-0.6090 (-3.37)	ECT^{-}(-1)	-0.8619 (-5.29)	ECT^{-}(-1)	-0.6220 (-2.70)	ECT^{-}(-1)	-0.2842 (-2.35)
MD1	0.0375 (2.18)	MD1	0.0262 (1.78)	MD1	-0.0753 -2.63)	MD5	0.0369 (2.05)
MD2	0.0260 (1.55)	MD10	-0.0412 (-2.75)	MD5	0.0458 (1.58)	MD10	-0.0332 (-1.78)
MD7	-0.0223 (-1.37)	…	…	MD6	0.0519 (1.87)	…	…
MD10	-0.0195 (-1.19)	…	…	MD10	-0.0515 (-1.93)	…	…

1. The lag lengths are in parentheses; the absence of a lag length indicates that the variable is not lagged. The superscripts plus (+) and minus (–) signs denote positive and negative changes, respectively, in the error correction term (ECT).

Note: Dependent variable: changes in farm price of beef (ΔFB)

speed compared to negative deviations. This reinforces the fact that Saskatchewan beef cattle farmers are price-takers in the market.

The estimated short-run dynamics reveals that the farm prices in Alberta and Ontario adjust contemporaneously and partially to changes in U.S. farm prices. Quebec farm prices, however, adjust more than completely to the changes in U.S. farm prices within four months. The estimated parameters also indicate that Saskatchewan farm prices adjust to changes in Alberta farm prices contemporaneously and almost completely. The short-run impact of BSE on farm prices as indicated by the estimated parameters in the BSE indices (ΔBS) is negative for all beef cattle producing provinces and appears with shorter lags and greater magnitude compared to the short-run impact on retail prices.

The short-run impact of quantity is positive and significant for Alberta, negative but insignificant for Ontario, and negative and significant for Quebec and Saskatchewan. The parameters in the demand shifters such as the retail prices of substitutes and per-capita disposable income are positive except in the Alberta model. The signs of the parameters in per-capita disposable income in the Alberta model are different for the first and the third lags indicating no net effect. Similar to the long-term relationship, the short-run impact of meat product manufacturing wages is estimated to be negative in the model for Quebec.

The parameters in the monthly dummies indicate that farm prices have tendencies to rise in January to February in Alberta, in January in Ontario, in May to June in Quebec and in May in Saskatchewan. They fall in July and October in Alberta, in October in Ontario, in January and October in Quebec, and October in Saskatchewan.

7.3 *Processing price model*

Price transmission between the farm gate and the processing firms at the provincial level cannot be modelled because of data limitation. In an attempt to discover the contribution of provincial farm prices to the national industrial price, a cointegration test (Table 6) is performed with the national industrial price series, farm price series for Alberta, Saskatchewan, Ontario and Quebec, quantity of beef entering the supply chain in Canada, and the BSE media count index[13]. While the hypothesis of no cointegrating relationship is rejected at the 1% level of significance, the hypothesis of at most one cointegrating relationship is rejected at the 10% level. In addition, the first five eigenvalues are considerably large. Hence, it is concluded that the cointegrating rank of the system is equal to one.

The results indicate that the national industrial price series has positive long-term relationships with farm prices in Ontario, Alberta and Saskatchewan (Table 6)[14]. Farm prices in Quebec, however, are in a negative long-term relationship with national

13. Other relevant data series such as meat product manufacturing wages, CPI for energy and US industrial prices of beef do not contribute to the cointegrating relationship.

14. A positive cointegrating vector implies a negative long-term relationship and vice versa.

industrial prices. This might be due to the fact that Quebec farm prices for beef cattle remained at the lowest level compared to the other three provinces between June 2003 and July 2005, regained a little in August 2005 to settle just above the level of Saskatchewan prices.

Table 6
Cointegration test statistics for the variables in the model for industrial beef prices

Series	Cointegration Vector	Eigenvalue[1]	H_0	Trace	5% C.V.
PB_t^{CA}	1.0000	0.4405	$r = 0$	151.60**	136.61
FB_t^{QC}	0.5135	0.3410	$r = 1$	100.49	104.94
FB_t^{ON}	-0.7819	0.2862	$r = 2$	63.79	77.74
FB_t^{SK}	-0.0151	0.1688	$r = 3$	34.13	54.64
FB_t^{AB}	-0.3540	0.1129	$r = 4$	17.86	34.55
QB_t^{CA}	0.2369	0.0600	$r = 5$	7.31	18.17
BS_t^{CA}	-0.0012	0.0211	$r = 6$	1.87	3.74

1. The eigenvalues are sorted from the highest to the lowest.
Notes: The 5% critical values (C.V.) are taken from Osterwald-Lenum (1992). The superscript ** denotes a 1% level of significance.

The vector for quantity is positive indicating a negative long-term relationship between industrial beef prices and quantities. The vector for the BSE media count index is, however, negative (i.e., positive relationship) suggesting that the industrial prices moved in the same direction as the index.

The dynamics of short-term adjustment of national industrial prices with provincial farm prices are captured in the results of the AECM (Table 7). The Wald test statistic fails to reject the null hypothesis of no asymmetry in overall adjustment of industrial prices in response to rising and falling farm prices in the provinces producing the major share of beef cattle. However, asymmetries in both magnitude and speeds of adjustment of industrial prices to rising and falling farm prices in Ontario and Quebec are evident in the estimated parameters.

The adjustments to rising and falling farm prices in Alberta and Saskatchewan are estimated to be symmetric. The estimates also suggest that positive deviations of industrial prices from the notional long-run equilibrium adjust at a relatively faster rate compared to negative deviations. Among others, quantity has an insignificant negative impact and the BSE media count index has a small positive impact on industrial prices. No seasonality in adjustment is detected in this case.

Table 7
Results of the estimated asymmetric error correction model for industrial prices of beef

Variable[1]	*Estimate (t-Stat)*	Variable[1]	*Estimate (t-Stat)*
ΔPB (-1)	0.2707 (2.32)	ΔFB^{AB+}(-1)	0.3549 (3.86)
ΔFB^{QC+}(-3)	0.2317 (2.55)	ΔFB^{AB-}(-1)	0.3857 (3.84)
ΔFB^{QC-} (-6)	0.1591 (1.99)	ΔQB^{CA} (-3)	-0.0374 (-1.14)
ΔFB^{ON+}(-5)	0.4578 (2.56)	ΔBS^{CA} (-4)	0.0002 (1.71)
ΔFB^{ON-}(-7)	0.1930 (1.50)	ECT^{+}(-1)	-0.7729 (-4.44)
ΔFB^{SK+}(-2)	0.2291 (3.25)	ECT^{-}(-1)	-0.4673 (-2.49)
ΔFB^{SK-}	0.2513 (3.13)	…	…

1. The lag lengths are in parentheses; the absence of a lag length indicates that the variable is not lagged. The superscripts plus (+) and minus (–) signs denote positive and negative changes, respectively, in the variables for the changes in farm prices of beef (ΔFB) and the error correction terms (ECT).

Note: Dependent variable: changes in industrial prices of beef (Δ*PB*)

8.0 Conclusions

This paper analyzes the dynamics of price transmission in the markets along the supply chain of beef and the impact of BSE on beef prices in Canadian provinces. Asymmetric Error Correction Models (AECMs) for retail prices are estimated for Alberta, British Columbia, Ontario and Quebec, the provinces that account for the major share of national demand. AECMs for farm prices are estimated for the major beef cattle producing provinces that include Alberta, Ontario, Quebec and Saskatchewan. An AECM for prices at the processing level is also estimated with national industrial prices of beef and provincial farm prices of beef cattle.

The results indicate that retail prices adjust faster and at a relatively greater magnitude to rising compared to falling industrial prices of beef. Industrial beef prices also adjust faster and at a relatively greater magnitude in response to increases in farm prices of beef cattle in Ontario and in Quebec than to decreases in farm prices in these provinces. However, industrial prices do not exhibit any significant overall asymmetry in terms of magnitude of adjustment to increases and decreases in farm prices in the producing provinces. A very small impact of BSE on retail prices is estimated, which has been negative for Alberta and Ontario, and positive for Quebec and British Columbia. The impact of BSE on industrial prices has also been small and positive. On the contrary, it is evident that BSE had a strong and sustained negative impact on farm prices in the beef cattle producing provinces.

Based on the above results, we draw the following overall implications. Asymmetries may have resulted from market imperfections in the retail beef markets in Quebec, Ontario, Alberta and British Columbia. Market imperfections in a weaker form may also exist in beef markets at the industrial level. Analysis of the presence and the form of market imperfections, however, requires in-depth study involving industrial prices data at the provincial level. Supply shocks due to BSE have negative impacts on farm prices both in the long-run and in the short-run. The impact of demand shocks on beef prices is generally substantial and persists for long periods. The impact of supply shocks on beef prices is generally small and, depending on the source of the shock, it may be for a shorter term or persist for a longer period.

The data for the beef cattle slaughter series are collected twice a year and monthly data are generated using fixed weights. Consequently, short-run variations in the series are not random, although the series may reveal a long-run trend. Therefore, the short-run responses relating to quantities of beef entering the supply chain may not reflect the reality. The lack of industrial prices data at the provincial level is also a limitation to a complete analysis of price transmission between producer, processor and retail levels. The concentration in beef processing and packing has been increasing in Canada and there has been an increase in the practice among packers (processors) to contract for their own cattle supplies and production. In order to analyze the impacts of these factors on prices, data availability in these areas will need to be "beefed up".

Acknowledgements

The authors wish to express their gratitude to Dr. Rakhal Sarker, Associate Professor, Department of Food, Agriculture and Resource Economics, University of Guelph, for his valuable suggestions relating to modelling and estimations. The cooperation of Lori Anderson (Library, Statistics Canada), Ron Morency and Danielle Gouin (Prices Division, Statistics Canada), Estelle Perrault, Cindy Carter and Patrick Lemire (Agriculture Division, Statistics Canada) in providing data is also thankfully acknowledged.

References

Bessler, D.A. 2005. A Time Series Analysis of Canadian Cattle and Beef Prices and Quantities Prior to and Following the May 2003 Discovery of BSE in the Canadian Cattle Herd, *Final Report for Competition Bureau Canada*, February 2005.

Canadian Food Inspection Agency. 2006. Canada's Assessment of the North American BSE Cases Diagnosed from 2003 to 2005 (Part II), http://www.inspection.gc.ca.

Competition Bureau Canada. 2005a. Competition Bureau concludes examination into Canadian cattle and beef pricing, http://www.competitionbureau.gc.ca.

Competition Bureau Canada. 2005b. Summaries of economic reports prepared for the Competition Bureau in its examination of cattle and beef industry pricing patterns before and since the onset of BSE. http://www.competitionbureau.gc.ca

Dickey, D.A., and W.A. Fuller. 1979. Distribution of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association*, 74: 427-431.

Engle, R.F. and C.W.J. Granger, 1987. Cointegration and error correction: representation, estimation and testing. *Econometrica*, 55: 251-276.

Gardner, B.L. 1975. The farm-retail spread in a competitive food industry. *American Journal of Agricultural Economics*, 57: 399-409.

Goodwin, B. and M. Holt. 1999. Price transmission and asymmetric adjustment in the US beef sector. *American Journal of Agricultural Economics*, 81(2): 630-637.

Granger, C.W.J. 1969. Investigating causal relationships by econometric models and cross spectral methods, *Econometrica*, 37: 424-438.

Granger, C.W.J. 1988. Some recent developments in the concept of causality, *Journal of Econometrics*, 39:199-211.

Granger, C.W.J. and T.H. Lee. 1989. Investigation of production, sales and inventory relationships using multicointegration and non-symmetric error correction models, *Journal of Applied Econometrics*, 4: 135-159.

Greene, W.H. 2003. *Econometric Analysis*, 5th edition, Upper Saddle River, N.J.: Prentice Hall.

Houck, J.P. 1977. An approach to specifying and estimating nonreversible functions, *American Journal of Agricultural Economics,* 59: 570-572.

Johansen, S. 1988. Statistical analysis of co-integrating vectors, *Journal of Economic Dynamics and Control*, 12: 231-254.

Johansen S. 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica,* 59: 551-1580.

Johansen, S. and K. Juselius. 1994. Identification of the long-run and the short-run structure: an application to the ISLM model. *Journal of Econometrics*, 63(1): 7-36.

Kinnucan, H.W. and O.D. Forker. 1987. Asymmetry in Farm-Retail Price Transmission for Major Dairy Products, *American Journal of Agricultural Economics* 69: 285-292.

Lloyd, T., S. McCorriston, W. Morgan, and T. Rayner. 2006. Food scares, market power and price transmission: the UK BSE crisis. *European Review of Agricultural Economics Advance Access,* March 2006: 1-29.

Love, A. 2005. An Investigation of the Effects of BSE on the Canadian Cattle and Beef Markets**.** *Report for Competition Bureau Canada*, 2005.

Osterwald-Lenum, M. 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics*, 54(3): 461-472.

Pantula, S.G., G. Gonzalez-Farias, and W. A. Fuller. 1994. A comparison of unit-root test criteria, *Journal of Business and Economic Statistics*, (October 1994): 449-459.

Peltzman, S. 2000. Prices rise faster than they fall, *Journal of Political Economy*, 108(3): 466-502.

Rapsomanikis, G., D. Hallam and P. Conforti. 2003. "Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and Applications" in *Commodity Market Review 2003-2004*, Food and Agriculture Organization of the United Nations, Rome, 2003.

United States Department of Agriculture. 1996. Weights, Measures and Conversion Factors for Agricultural Commodities and Their Products, ERS, USDA, *Agricultural Handbook Number 697*.

Ward, R.W. 1982. Asymmetry in retail, wholesale and shipping point pricing for fresh vegetables, *American Journal of Agricultural Economics*, 62: 205-212.

World Health Organization. 2006. Bovine spongiform encephalopathy, Fact Sheet no. 113, http://www.who.int/mediacentre/factsheets/fs113/en

Appendix A

The supply chain of beef is characterized by a concentrated processing industry producing processed products and selling them to a concentrated retail industry. It is often argued that higher levels of concentration may induce the relevant agents to exercise market power at different levels of markets along the supply chain. Market power in the form of oligopoly or oligopsony may affect prices, and thus, contribute to asymmetries in price transmission. The following provides an analysis of the effects of market power in different forms and combinations on market outcomes at different levels of the markets.

First, probable market imperfections at the retail level are considered. With a measure for oligopolistic behaviour of the retailers, the perceived marginal revenue curve of the retailers, PMR_R, is derived from the retail demand function in equation (3.3) as:

$$PMR_R = a_0 - (1+\phi_R)a_1 Q + a_3 P_R^S + a_3 X \qquad \text{(A.1)}$$

where ϕ_R is the index of oligopoly power of the retailers. A value of $\phi_R = 0$ signifies a competitive retail market, while $\phi_R = 1$ refers to a monopoly. In an oligopolistic retail market, the derived demand at the processing level in equation (3.5) changes to:

$$DD'_R = PMR_R - MC_R = a_0 - c_1 - (1+\phi_R)a_1 Q + a_2 P_R^S + a_3 X - b_2 W_R \qquad \text{(A.2)}$$

The retailers may also exercise oligopsony power in the wholesale market. In that case, the perceived marginal expenditure curve of the retailers, PME_R, is derived from the supply (marginal cost) function of the processed product in equation (3.6) as:

$$PME_R = P_P + \varphi_R c_1 Q = b_0 + m_1 + (1+\varphi_R)b_1 Q + b_2 Z + m_2 W_P \qquad \text{(A.3)}$$

where φ_R is the index of oligopsony power of the retailers. A value of $\varphi_R = 0$ implies that the retailers are price takers in the wholesale market, while $\varphi_R = 1$ refers to a monopsony.

Concentration in the processing industry may also lead to a situation that allows the processors to exercise oligopoly at the processed product market. To account for such a situation, the perceived marginal revenue function of the processors is obtained from the derived demand in equation (3.5), which is the demand faced by the processors. Thus, with an index of processors' oligopoly, ϕ_P, the perceived marginal revenue curve of the processors can be written as:

$$PMR_P = a_0 - c_1 - (1+\phi_P)a_1 Q + a_2 P_R^S + a_3 X - b_2 W_R \qquad \text{(A.4)}$$

However, if the retailers are oligopolistic, the demand faced by the processors is the derived demand given in equation (A.2). In that case, the perceived marginal revenue function of the processors changes as follows:

$$PMR'_P = a_0 - c_1 - (1+\phi_P)(1+\phi_R)a_1 Q + a_2 P_R^S + a_3 X - b_2 W_R \qquad \text{(A.4a)}$$

It is worth noting that the parameters ϕ_R and ϕ_P represent aggregate conjectural variations of the retail and the processing firms, respectively, in the relevant output market such that $\phi_R = \sum_i^n (\partial Q / \partial Q_i)$ and $\phi_P = \sum_i^n (\partial Q / \partial Q_i)$. Conversely, the parameters φ_P and φ_F represent aggregate conjectural variations of the retail and the processing firms, respectively, in the relevant input markets such that $\varphi_R = \sum_i^n (\partial Q / \partial Q_i)$ and $\varphi_P = \sum_i^n (\partial Q / \partial Q_i)$. The parameters ϕ_R and ϕ_P are used as indices of oligopoly, and φ_R and φ_P as indices of oligopsony. Using the above equations, some probable situations of oligopoly and oligopsony and their effects on prices and margins are derived below.

Retailers' oligopoly and oligopsony

The following market outcomes are obtained on the basis of assumptions that the retailers may exercise some degree of oligopoly in the retail market and some degree of oligopsony in the processed product market. The processors and the farmers are assumed to be price-takers. In such a case, equilibrium is at the intersection of equations (A.2) and (A.3) from which the following price equations can be solved:

$$P_F = \frac{k + (\phi_R a_1 + \varphi_R b_1 + a_1) b_2 Z + b_1 (a_2 P_R^S + a_3 X - c_2 W_R - m_2 W_P)}{(1+\phi_R)a_1 + (1+\varphi_R)b_1}, \qquad \text{(A.5)}$$

where $k = b_0[(1+\phi_R)a_1 + (1+\varphi_R)b_1] + b_1 k$.

$$P_P = P_F + m_1 + m_2 W_P \qquad \text{(A.6)}$$

$$P_R = P_P + \frac{k' + c_2 W_R (a_1 + b_1) + (\phi_R a_1 + \varphi_R b_1)(a_2 P_R^S + a_3 X - b_2 Z - m_2 W_P)}{(1+\phi_R)a_1 + (1+\varphi_R)b_1}, \qquad \text{(A.7)}$$

where $k' = (a_0 - b_0 - m_1)(\phi_R a_1 + \varphi_R b_1) + c_1(a_1 + b_1)$.

When the retail industry is competitive (i.e., absence of oligopoly and oligopsony), equation (A.7) reduces to: $P_R = P_P + c_1 + c_2 W_R$.

In the absence of retailers' oligopsony in the processed product market, the parameter φ_R is equal to zero. Therefore, to account for an oligopolistic retail product market and a competitive processed product market, the factor $\varphi_R b_1$ has to be excluded from the numerators and the denominators of equations (A.5) and (A.7). In equation (A.7), significant estimates of the parameters in P_R^S, X, *Z*, and W_P can be obtained only if one of the market power parameters is significantly different from zero.

Oligopolistic retailers and processors: Bilateral oligopoly

In case of bilateral oligopoly, the intersection of equations (3.6) and (A.4a) provides the equilibrium. The retail price is determined on the retail demand, while the processors charge the retailers a price on the derived demand function as defined in equation (A.2). The price equations are obtained as follows:

$$P_F = \frac{k + (a_1 + \phi_P a_1 + \phi_R a_1 + \phi_P \phi_R a_1) b_2 Z + b_1 (a_2 P_R^S + a_3 X - c_2 W_R - m_2 W_P)}{(1+\phi_P)(1+\phi_R) a_1 + b_1}, \qquad \text{(A.8)}$$

where $k = [(1+\phi_P)(1+\phi_R)a_1 + b_1]b_0 + b_1 k$.

$$P_P = P_F + \frac{k' + (\phi_P a_1 + \phi_P \phi_R a_1)(a_2 P_R^S + a_3 X - b_2 Z - c_2 W_R) + (a_1 + b_1 + \phi_R a_1) m_2 W_P}{(1+\phi_P)(1+\phi_R) a_1 + b_1}, \qquad \text{(A.9)}$$

where $k' = \phi_P a_1 (2 + \phi_R) - \phi_R k + m_1 (a_1 + b_1)$.

$$P_R = P_P + \frac{k'' + [(a_1 + \phi_P a_1 + \phi_P \phi_R a_1) + b_1] c_2 W_R + \phi_R a_1 (a_2 P_R^S + a_3 X - b_2 Z - m_2 W_P)}{(1+\phi_P)(1+\phi_R) a_1 + b_1}, \qquad \text{(A.10)}$$

where $k'' = [(1+\phi_P)(1+\phi_R)a_1 + b_1]c_1 + \phi_R a_1 k$.

The retail price equations in (A.7) and (A.10) have the same set of the right hand side variables, the parameters of which are influenced by market power indices. The processing price equations in (A.6) and (A.9) are, however, different. Processing price in equation (A.6) is equal to farm price and the processing cost. In contrast, the parameters in P_R^S, X, Z, and W_R equation (A.9) are expected to be significant in the presence of oligopoly at the processed product market (i.e., ϕ_P is significantly different from zero). It can be noted that equations (A.9) and (A.10) reduce to $P_P = P_F + m_1 + m_2 W_P$ and $P_R = P_P + c_1 + c_2 W_R$, respectively, in competitive markets.

Retailers' oligopsony and processors' oligopoly: Countervailing market power

In a scenario of so-called countervailing market power (CMP), the equilibrium is at the intersection of equations (A.3) and (A.4). Depending on relative bargaining power of the retailers and the processors, the processed product price settles at a point above the marginal cost of the processors and below the derived demand. To keep the algebra simple, it is assumed that the processors' price settles on the perceived marginal revenue function of the processors. Thus, the prices and equations can be obtained as follows:

$$P_F = \frac{k + (\phi_P a_1 + \varphi_R b_1 + a_1) b_2 Z + b_1 (a_2 P_R^S + a_3 X - c_2 W_R - m_2 W_P)}{(1+\phi_P) a_1 + (1+\varphi_R) b_1}, \quad \text{(A.11)}$$

where $k = b_0[(1+\phi_P)a_1 + (1+\varphi_R)b_1] + b_1 k$.

$$P_P = P_F + \frac{k' + \varphi_R b_1 (a_2 P_R^S + a_3 X - b_2 Z - c_2 W_R) + (a_1 + b_1 + \phi_P a_1)(m_2 W_P)}{(1+\phi_P) a_1 + (1+\varphi_R) b_1}, \quad \text{(A.12)}$$

where $k' = (a_1 + b_1 + \phi_P a_1) m_1 + \varphi_R b_1 (a_0 - b_0 - c_1)$.

$$P_R = P_P + \frac{k'' + (a_1 + b_1 + \varphi_R b_1) c_2 W_R + \phi_P a_1 (a_2 P_R^S + a_3 X - b_2 Z - m_2 W_P)}{(1+\phi_P) a_1 + (1+\varphi_R) b_1}, \quad \text{(A.13)}$$

where $k'' = c_1[(1+\phi_P)a_1 + (1+\varphi_R)b_1] + \phi_P a_1 k$.

The equations for retail prices in bilateral oligopoly and countervailing market power scenarios are similar except for the indices of market power. However, for processors' price, the expected signs of the parameters in P_R^S , X , Z, and W_R are likely to change in equation (A.9), but remain unchanged in equation (A.12)[15]. In absence of CMP, equations (A.12) and (A.13) reduce to $P_P = P_F + m_1 + m_2 W_P$ and $P_R = P_P + c_1 + c_2 W_R$, respectively.

15. The parameter a_1 is negative, and b_1, ϕ and φ are positive by definition. The denominator would be positive as supply response is expected to be greater than the demand response. When ϕ is significantly different from zero in equation (A.9), its multiplication with a_1 would produce a negative number.

Agriculture and Rural Working Paper Series

(* The *Agriculture and Rural Working Paper Series* is now available on Statistics Canada's Web Site (www.statcan.gc.ca). From the Statistics Canada *Home* page, select *Publications* and then choose *Free internet publications*.

No.1	(21-601-MPE1980001)	**A Description of Theil's RMPSE Method in Agricultural Statistical Forecasts (1980)**, Stuart Pursey
No.3	(21-601-MPE1981003)	**A Review of the Livestock Estimating Project with Recommendations for the Future (1981)**, Bernard Rosien and Elizabeth Leckie
No.4	(21-601-MPE1984004)	**An Overview of the Canadian Oilseed Industry (1984)**, Glenn Lennox
No.5	(21-601-MPE1984005)	**Preliminary Analysis of the Contribution of Direct Government Payments to Realized Net Farm Income (1984)**, Lambert Gauthier
No.6	(21-601-MPE1984006)	**Characteristics of Farm Entrants and their Enterprises in Southern Ontario for the Years 1966 to 1976 (1984)**, Jean B. Down
No.7	(21-601-MPE1984007)	**A Summary of Commodity Programs in the United States (1984)**, Allister Hickson
No.8	(21-601-MPE1984008)	**Prairie Summerfallow Intensity: An Analysis of 1981 Census Data (1984)**, Les Macartney
No.9	(21-601-MPE1985009)	**The Changing Profile of the Canadian Pig Sector (1985)**, Mike Shumsky
No.10	(21-601-MPE1986010)	**Revisions to the Treatment of Imputed House Rents in the Canadian Farm Accounts, 1926-1979 (1986)**, Mike Trant
No.11	(21-601-MPE1992011)	**The Ratio Estimator: an Intuitive Explanation and Its Use in Estimating Agriculture Variables (1992)**, François maranda and Stuart Pursey
No.12	(21-601-MPE1991012)	**The Impact of Geographic Distortion Due to the Headquarters Rule (1991)**, Rick Burroughs
No.13	(21-601-MPE1991013)	**The Quality of Agriculture Data - Strengths and Weaknesses (1991)**, Stuart Pursey
No.14	(21-601-MPE1992014)	**Alternative Frameworks for Rural Data (1992)**, A.M. Fuller, Derek Cook and Dr. John Fitzsimons
No.15	(21-601-MPE1993015)	**Trends and Characteristics of Rural and Small Town Canada (1993)**, Brian Bigs, Ray Bollman and Michael McNames
No.16	(21-601-MPE1992016)	**The Microdynamics and Farm Family Economics of Structural Change in Agriculture (1992)**, Phil Ehrensaft and Ray Bollman
No.17	(21-601-MPE1993017)	**Grains and Oilseeds Consumption by Livestock and Poultry, Canada and Provinces 1992**, Livestock and Animal Products Section
No.18	(21-601-MPE1994018)	**Trends and Patterns of Agricultural Structural Change: Canada / US Comparison**, Ray Bollman, Leslie A. Whitener and Fu Lai Tung
No.19	(21-601-MPE1994019)	**Farm Family Total Income by Farm Type, Region and Size for 1990 (1994)**, Saiyed Rizvi, David Culver, Lina Di Piétro and Kim O'Connor
No.20	(21-601-MPE1991020)	**Adjustment in Canadian Agriculture (1994)**, George McLaughlin
No.21	(21-601-MPE1993021)	**Microdynamics of Farm Size Growth and Decline: A Canada-United States Comparison**, Fred Gale and Stuart Pursey
No.22	(21-601-MPE1992022)	**The Structures of Agricultural Household Earnings in North America: Positioning for Trade Liberalization**, Leonard Apedaile, Charles Barnard, Ray Bollman and Blaine Calkins
No.23	(21-601-MPE1992023)	**Potatoes: A Comparison of Canada/USA Structure**, Glenn Zepp, Charles Plummer and Barbara McLaughlin
No.24	(21-601-MPE1994024)	**Farm Structure Data: A US-Canadian Comparative Review**, Victor J. Oliveira, Leslie A. Whitener and Ray Bollman
No.25	(21-601-MPE1994025)	**Grain Marketing Statistics Statistical Methods Working Paper Version 2**, Karen Gray

Agriculture and Rural Working Paper Series (continued)

(* The *Agriculture and Rural Working Paper Series* is now available on Statistics Canada's Web Site (www.statcan.gc.ca). From the Statistics Canada *Home* page, select *Publications* and then choose *Free internet publications*.

No.26	(21-601-MPE1994026)	**Farm Business Performance: Estimates from the Whole Farm Database**, W. Steven Danford
No.27	(21-601-MPE1994027)	**An Attempt to Measure Rural Tourism Employment**, Brian Biggs
No.28*	(21-601-MIE1995028)	**Delineation of the Canadian Agricultural Ecumene for 1991**, Timothy J. Werschler
No.29	(21-601-MPE1995029)	**Mapping the Diversity of Rural Economies: A preliminary Typology of Rural Canada**, Liz Hawkins
No.30*	(21-601-MIE1996030)	**Structure and Trends of Rural Employment: Canada in the Context of OECD Countries**, Ron Cunningham and Ray D. Bollman
No.31*	(21-601-MIE1996031)	**A New Approach to Non-CMA/CA Areas**, Linda Howatson-Leo and Louise Earl
No.32	(21-601-MPE1996032)	**Employment in Agriculture and Closely Related Industries in Rural Areas: Structure and Change 1981-1991**, Sylvain Cloutier
No.33*	(21-601-MIE1998033)	**Hobby Farming - For Pleasure or Profit?**, Stephen Boyd
No.34*	(21-601-MIE1998034)	**Utilization of Document Imaging Technology by the 1996 Canadian Census of Agriculture**, Mel Jones and Ivan Green
No.35*	(21-601-MIE1998035)	**Employment Patterns in the Non-Metro Workforce**, Robert Mendelson
No.36*	(21-601-MIE1998036)	**Rural and Small Town Population is Growing in the 1990s**, Robert Mendelson and Ray D. Bollman
No.37*	(21-601-MIE1998037)	**The Composition of Business Establishments in Smaller and Larger Communities in Canada**, Robert Mendelson
No.38*	(21-601-MIE1998038)	**Off-farm Work by Census-farm Operators: An Overview of Structure and Mobility Patterns**, Michael Swidinsky, Wayne Howard and Alfons Weersink
No.39*	(21-601-MIE1999039)	**Human Capital and Rural Development: What Are the Linkages?**, Ray D. Bollman
No.40*	(21-601-MIE1999040)	**Computer Use and Internet Use by Members of Rural Households**, Margaret Thompson-James
No.41*	(21-601-MIE1999041)	**RRSP Contributions by Canadian Farm Producers in 1994**, Marco Morin
No.42*	(21-601-MIE1999042)	**Integration of Administrative Data with Survey and Census Data**, Michael Trant and Patricia Whitridge
No.43*	(21-601-MIE2001043)	**The Dynamics of Income and Employment in Rural Canada: The Risk of Poverty and Exclusion**, Esperanza Vera-Toscano, Euan Phimister and Alfons Weersink
No.44*	(21-601-MIE2001044)	**Rural Youth Migration Between 1971 and 1996**, Juno Tremblay
No.45*	(21-601-MIE2001045)	**Measuring Economic Well-Being of Rural Canadians Using Income Indicators**, Carlo Rupnik, Margaret Thompson-James and Ray D. Bollman
No.46*	(21-601-MIE2001046)	**The Geographical Patterns of Socio-Economic Well-Being of First Nations Communities in Canada**, Robin P. Armstrong
No.47*	(21-601-MIE2001047)	**Distribution and Concentration of Canadian Livestock**, Martin S. Beaulieu
No.48*	(21-601-MIE2001048)	**Intensive Livestock Farming: Does Farm Size Matter?**, Martin S. Beaulieu
No.49*	(21-601-MIE2001049)	**Agriculture Statistics for Rural Development**, Ray D. Bollman
No.50*	(21-601-MIE2001050)	**Rural and Small Town Employment: Structure by Industry**, Roland Beshiri and Ray D. Bollman

Agriculture and Rural Working Paper Series (continued)

(* The *Agriculture and Rural Working Paper Series* is now available on Statistics Canada's Web Site (www.statcan.gc.ca). From the Statistics Canada *Home* page, select *Publications* and then choose *Free internet publications*.

No.51*	(21-601-MIE2001051)	**Working Time: How do Farmers Juggle with it and How has it Impacted Their Family Total Income**, Sylvain Cloutier
No.52*	(21-601-MIE2001052)	**Growers of Genetically Modified Grain Corn and Soybeans in Quebec and Ontario: A Profile**, Bernard Hategekimana
No.53*	(21-601-MIE2002053)	**Integration of Canadian and U.S. Cattle Markets**, Rita Athwal
No.54*	(21-601-MIE2002054)	**Genetically Modified Grain Corn and Soybeans in Quebec and Ontario in 2000 and 2001**, Bernard Hategekimana
No.55*	(21-601-MIE2002055)	**Recent Migration Patterns in Rural and Small Town Canada**, Neil Rothwell et al
No.56*	(21-601-MIE2002056)	**Performance in the Food Retailing Segment of the Agri-Food Chain**, David Smith and Michael Trant
No.57*	(21-601-MIE2002057)	**Financial Characteristics of Acquired Firms in the Canadian Food Industry**, Martin S. Beaulieu
No.58*	(21-601-MIE2002058)	**Provincial Trade Patterns**, Marjorie Page
No.59*	(21-601-MIE2002059)	**An Analysis of Profits within the Canadian Food Processing Sector**, Rick Burroughs and Deborah Harper
No.60*	(21-601-MIE2002060)	**Rural Diversification**, Marjorie L. Page
No.61*	(21-601-MIE2002061)	**Definitions of "Rural"**, Valerie du Plessie et al
No.62*	(21-601-MIE2003062)	**A Geographic Profile of Canadian Livestock**, Martin S. Beaulieu and Frédéric Bédard
No.63*	(21-601-MIE2003063)	**Sub-provincial Income Disparity in Canada: Evidence from 1992 to 1999**, Alessandro Alasia
No.64*	(21-601-MIE2003064)	**Canada – Mexico Agricultural Economies and Trade Under Closer North American Relations**, Verna Mitura et al
No.65*	(21-601-MIE2003065)	**Computer Technology Adoption by Canadian Farm Businesses: An Analysis Based on the 2001 Census of Agriculture**, Jean Bosco Sabuhoro and Patti Wunsch
No.66*	(21-601-MIE2004066)	**Factors Associated with Household Internet Use in Canada**, Vik Singh
No.67*	(21-601-MIE2004067)	**Mapping the Socio-Economic Diversity of Rural Canada: A Multivariate Analysis**, Alessandro Alasia
No.68*	(21-601-MIE2004068)	**The Effect of FDI on Agriculture and Food Trade: An Empirical Analysis**, W.H. Furtan and J.J. Holzman
No.69*	(21-601-MIE2004069)	**Canada's Beef Cattle Sector and the Impact of BSE on Farm Family Income**, Verna Mitura and Lina Di Piétro
No.70*	(21-601-MIE2004070)	**Measuring Industry Concentration in Canada's Food Processing Sectors**, Darryl Harrison and James Rude
No.71*	(21-601-MIE2004071)	**Trends in Non-farm Self-employment Activity for Rural Women**, Valerie du Plessis
No.72*	(21-601-MIE2004072)	**The Redesign of the Canadian Farm Product Price Index**, Andy Baldwin
No.73*	(21-601-MIE2005073)	**Effect of Urbanization on the Adoption of Environmental Management Systems in Canadian Agriculture**, Udith Jayasinghe-Mudalige, Alfons Weersink, Brady Deaton, Martin Beaulieu and Mike Trant
No.74*	(21-601-MIE2005074)	**Factors Leading to the Implementation of Beneficial Management Practices for Manure Management on Canadian Hog Operations**, Diep Le and Martin S. Beaulieu

Agriculture and Rural Working Paper Series (concluded)

(* The *Agriculture and Rural Working Paper Series* is now available on Statistics Canada's Web Site (www.statcan.gc.ca). From the Statistics Canada *Home* page, select *Publications* and then choose *Free internet publications*.

No.75*	(21-601-MIE2005075)	**The Competitiveness of Canada's Poultry Processing Industry**, Hao Liu et al
No.76*	(21-601-MIE2005076)	**Skills, Innovation and Growth: Key Issues for Rural and Territorial Development – A Survey of the Literature**, Alessandro Alasia
No.77*	(21-601-MIE2006077)	**A Geographical Profile of Manure Production in Canada**, **2001**, Nancy Hofmann and Martin S. Beaulieu
No.78*	(21-601-MIE2006078)	**Factors Affecting Biotechnology Innovation in Canada: Analysis of the 2001 Biotechnology Use and Development Survey**, Daryl van Moorsel, J.A.L. Cranfield and David Sparling
No.79*	(21-601-MIE2006079)	**An Analysis of Financing Innovation and Commercialization in Canada's Functional Food and Nutraceutical Sector**, John Cranfield, Deepananda Herath, Spencer Henson and Dave Sparling
No.80*	(21-601-MIE2006080)	**Impact of Characteristics of the Farmers and their Business on Profitability in the Canadian Hog Industry**, Véronique Maltais
No.81*	(21-601-MIE2006081)	**The Demographic Overlap of Agriculture and Rural**, Ray D. Bollman
No.82*	(21-601-MIE2006082)	**Northern Ontario's Communities: Economic Diversification**, **Specialization and Growth**, Ray D. Bollman, Roland Beshiri and Verna Mitura
No.83*	(21-601-MIE2007083)	**Factors Driving Canada's Rural Economy**, Ray D. Bollman
No.84*	(21-601-MIE2007084)	**Risk Factors Associated with Farm Injuries in Canada**, Véronique Maltais
No.85*	(21-601-MIE2007085)	**Off-farm Labour Decisions of Canadian Farm Operators in 2001: The Role of Operator, Farm, Community and Regional Determinants**, Alessandro Alasia, Ray D. Bollman, Alfons Weersink and John Cranfield
No.87*	(21-601-MIE2007087)	**Estimation of Water Use in Canadian Agriculture in 2001**, Martin S. Beaulieu, Caroline Fric and François Soulard
No.88*	(21-601-MIE2007088)	**An Index of Community Vulnerability: Conceptual Framework and Application to Population and Employment Changes**, Alessandro Alasia, Ray Bollman, John Parkins and Bill Reimer
No.89*	(21-601-MIE2007089)	**Pesticide Use and Pest Management Practices of Canadian Apple Growers**, Martin S. Beaulieu, Tim MacDonald, Charles Benbrook and Pierre Mineau
No.90*	(21-601-MIE2007090)	**Structure and Change in Canada's Rural Demography: An Update to 2006 with Provincial Detail**, Ray D. Bollman and Heather A. Clemenson