Do inventories have an impact on price transmission? Evidence from the Canadian chicken industry

Abbassi, Abdessalem and Tamini, Lota D. and Gervais, Jean-Philippe

1 January 2011

Do inventories have an impact on price transmission? Evidence from the Canadian chicken industry[1]

Abdessalem Abbassi
Adjunct Professor
Department of Agricultural Economics and Consumer Studies and CRÉA,
Laval University

Lota D. Tamini
Assistant Professor
Department of Agricultural Economics and Consumer Studies and CRÉA,
Laval University

Jean-Philippe Gervais
Associate Professor
Department of Agricultural and Resource Economics,
North Carolina State University

January 2011

Abstract: This paper investigates the influence of inventories in explaining the magnitude of price transmission. The empirical strategy consists of two distinct steps. First, the flexible non-linear framework of Hamilton is used to investigate the influence of inventories on price transmission. The procedure detects significant non-linearities and suggests that the price transmission elasticity is increasing in the level of the farm price and decreasing in the ratio of inventories to sales. This evidence leads to specific functional forms for the price transmission and target inventory equations which are estimated in a second step. The estimation procedure accounts for potential simultaneity between sales at the wholesale level and the wholesale price. Our results suggest that price transmission is lower (higher) when inventories are below (above) a target which is function of domestic sales.

Keywords: Asymmetric price transmission; inventories.

J.E.L. Classification: C22; Q11

---

[1] Gervais is the contact author: Department of Agricultural and Resource Economics, North Carolina State University, Campus Box 8109, Raleigh, NC, 27695; email: JP_Gervais@ncsu.edu. The authors acknowledge the use of computer codes made publicly available by Prof. James D. Hamilton. Other computer codes developed by the authors are available upon request.

Do inventories have an impact on price transmission?
Evidence from the Canadian chicken industry

1. Introduction

The empirical literature on Asymmetric Price Transmission (APT) in agri-food supply chains has grown significantly in recent years. This interest in APT appears motivated by concerns relative to concentration among input suppliers and downstream processing and retailing firms. Recently, McCorriston et al. (2001), Carman and Sexton (2005) and Lloyd et al. (2006) studied empirically the linkages between market power and price transmission.[1] However, market power is certainly not the only cause of APT observed in retail-farm margins. Risk and expectations, innovation, menu costs of changing prices, government intervention, changes in consumer preferences, perishability of products and inventory management strategies are all factors that can explain APT in agri-food supply chains (Wohlgenant, 2001).

There are formal theoretical arguments that link inventories to price transmission. Wohlgenant (1985) proposed a rational expectations model to explain those linkages using a profit maximization framework in which a competitive firm maximizes present value of expected net revenues from inventory holdings. Deaton and Laroque (1992) analyzed the behaviour of commodity prices under storage. They showed that inventory demand is more elastic at lower prices. Hence, a shock at higher prices (when inventories are low) triggers a larger price reaction in the supply chain than an identical shock when prices are low.

The Canadian chicken market offers an interesting setting to investigate the influence of inventories on price transmission. Canadian chicken producers rely on supply management and protection at the border[2] to support the farm gate price. In short, output in each province is determined using a bottom-up approach through which processors survey market opportunities, and relay their demand of live chickens to the producers' marketing boards in each province. The provincial boards relay their output requirements to Chicken Farmers of Canada (CFC) who then adjust provincial market shares to sum to the chicken quota allocation at the national level. Between 1992 and 2002, farm prices were determined through negotiations between chicken producers' marketing boards and processors in each province. Since May 2003, the farm price in Ontario (generally used as a basis for the price negotiations in the other provinces) is now explicitly tied to producers' average costs. This price mechanism is often referred to as "cost-plus" pricing. Output restrictions at the farm level combined with predetermined farm prices imply a role for inventories in balancing unexpected demand and supply shocks, as well as a causality relationship between farm and wholesale prices.

Deaton and Laroque (1992)'s argument can easily be transposed to the Canadian chicken supply chain. Suppose there is an increase in the cost structure of producers which moves the farm supply inward and thus raises the farm price. As a result, the processors' supply curve will also shift inward. The magnitude of the impact on the wholesale price following the shock at the farm level however will depend on the demand's elasticity. Consider a situation in which inventories are low (high wholesale price) and thus the use plus storage demand is inelastic. The shock on the farm price will cause the wholesale price to increase by a greater percentage than when inventories are large (and thus use plus storage demand will be made more elastic). As a result, one is likely to witness a larger (smaller) response in the wholesale price following a change in the farm price if inventories are below (above) the target level.

Meyer and von Cramon-Taubadel (2004) divide up APT into two broad categories[3]: magnitude and speed. APT in magnitude refers to the response in the output price made conditional on the direction of the change in the input price. APT in speed refers to the pace of the response in the output price made conditional on the direction of the change in the input price. It is fair to say that a significant share of APT studies in the literature focus on the latter type of asymmetry (*e.g.,* Goodwin and Holt, 1999; Abdulai, 2002; Serra and Goodwin, 2003; Chavas and Mehta, 2004; Ben-Kaabia and Gil, 2007). In general, these studies rely on some form of threshold behaviour to account for the different speed to which prices return to their long-run equilibrium. The literature on asymmetry in the magnitude of price transmission is thinner. Miller and Hayenga (2001) investigated APT in the U.S. hog/pork industry by dividing the observations into low and high frequency price cycles. They subsequently uncovered APT in the time domain. Lass (2005) used linear methods (in the spirit of Houck, 1977; and Ward, 1982) applied to non-linear transformations of integrated variables to test for APT in the U.S. dairy industry. Llyod et al. (2006) investigated APT in the U.K. cattle/beef supply chain and Gervais (2010) examined potential non-linearities in both the speed and magnitude of price transmission in the U.S. hog/pork supply chain.

This paper proposes to analyze APT using an empirical framework based on insights from the macroeconomics literature on Linear-Quadratic (LQ) inventory models (*e.g.,* Blanchard, 1983; West, 1995; and Hamilton, 2002). Usually, inventories are used to smooth unanticipated fluctuations in demand and prevent stocking out. LQ inventory models assume that inventory costs are a quadratic function of the difference between the end-of-period inventories and a target inventory. The latter is generally specified as a linear function of the current period's sales. While some studies[4] explicitly identified inventories as a potential source of asymmetry in price transmission, Meyer and von Cramon-Taubadel (2004) note that no studies ever documented quantitatively the impact of inventories on the degree of APT. Abbassi and Gervais (2010) provided structural estimates of a linear-quadratic inventory model in the context of an agri-food supply chain, but they do not address price transmission in the supply chain. The purpose of the paper is to fill this gap in the literature by investigating empirically the impacts of inventories on price transmission.

The empirical relationship between price transmission and inventories is partly based on Borenstein, Cameron and Gilbert (1997) and Borenstein and Shepard (2002) who investigated price transmission between crude oil and gasoline markets. The arguments of the former study slightly depart from the LQ inventory models because the authors essentially rely on some form of cost asymmetry when changing inventories. Inventories must be nonnegative and thus they argue that the cost of decreasing inventories must increase substantially at some point. In other words, the expected costs of stocking-out must be greater than costs of building-up inventories. Borenstein and Shepard (2002) focus on the existence of adjustment costs in production to explain why firms spread adjustments in output over time.

The empirical strategy consists of two distinct steps. First, the flexible non-linear framework of Hamilton (2001, 2003) is used to investigate the influence of inventories on price transmission. The procedure detects significant non-linearities and suggests that the price transmission elasticity is increasing in the level of the farm price and decreasing in the ratio of inventories to sales. This evidence leads to specific functional forms for the price transmission and target inventory equations which are estimated in a second step. The estimation procedure accounts for potential simultaneity between sales at the wholesale level and the wholesale price. Our results suggest that price transmission is lower (higher) when inventories are below (above) a target which is function of domestic sales.

2. Data

Our study involves analysing wholesale-farm price spread.[5] Data on monthly chicken farm prices in Ontario from April 1992 to November 2003 were obtained from Chicken Farmers of Canada (CFC). CFC also supplied a weighted average of monthly wholesale prices in Ontario based on different chicken cuts. Figure 1 presents the pattern of the farm and wholesale prices in Ontario. The wholesale price is more volatile than the farm price (on an eviscerated basis). This is consistent with an objective of supply management which is to stabilize farm receipts. A preliminary investigation of the potential correlation between the two prices is provided in figure 2. It illustrates the relationship between the natural log of the farm price and the natural log of the price received by processing firms. There is an apparent positive correlation between the two prices although the coefficient of determination $\left(R^2\right)$ of a linear regression is not especially high at 0.46.

Data on monthly inventories and chicken production in the province of Ontario from April 1992 to November 2003 were also obtained from CFC. Domestic sales were proxied by the current period output minus the difference in the end-of-period inventory level of the current and previous periods.[6] Figure 3 illustrates the growth in domestic sales of chicken meat accompanied by the proportional growth in inventories of chicken products. Figure 4 details the correlation between monthly inventories and domestic sales. The positive linear relationship is more significant than for the price relationship as the coefficient of determination is 0.76.

Before estimating the relationship between wholesale and farm prices, the stochastic properties of the data need to be investigated. The residual-based stationary bootstrap procedure of Parker, Paparoditis and Politis (2006) is used to investigate if the series are integrated of order one. The procedure has overwhelmingly better power in small samples than the usual asymptotic tests which tend to under reject the null hypothesis of a unit root (Maddala and Kim, 1998). Consider a time series X_t and define the (centered) residuals $\hat{v}_t = X_t - \hat{\rho} X_{t-1}$ where $\hat{\rho}$ is the Ordinary Least Squares (OLS) estimate of the model: $X_t = \rho X_{t-1} + v_t$. The idea is to sample from blocks of residuals whose length is randomly selected using a geometric distribution with parameter q. A bootstrap sample is formed by setting the first observation of the bootstrap sample to its sample value $\left(X_1^* = X_1\right)$. The second observation in the bootstrap sample is: $X_2^* = X_1^* + v_2^*$; where $v_2^* = \hat{v}_t$ is randomly selected. The following observation is: $X_3^* = X_2^* + v_3^*$; where $v_3^* = \hat{v}_{t+1}$ with probability $1-q$ or $X_3^* = X_2^* + v_s^*$ $s = 1,\ldots,T$ with probability q.

The sample simulated with the above procedure mimics the original series and is consistent with the null hypothesis of a unit root. Using the bootstrap sample, the OLS estimate $\hat{\rho}^*$ is computed. This procedure is repeated B times and the empirical rejection probabilities can be computed. In practice, there is no widely accepted process to select the parameter of the geometric distribution. We experimented with a few different parameters to find it did not change the qualitative nature of the results and chose to report the results for $q = 0.1$ with 2,000 repetitions. As for the usual asymptotic unit root tests, there is no *a priori* agreed procedure to decide if the OLS regression should include a drift. Hence, table 1 reports the p-value of the null hypothesis of a unit root with and without a drift included in the bootstrap regression.

Figure 3 strongly suggests that a drift variable should be included for the sales and inventory variables because both variables are trending upward. The null hypothesis of a unit root is strongly rejected when a drift variable is included. Visual inspection of the farm and wholesale price series in Figure 1 does not produce undisputable evidence for or against the inclusion of a drift in the unit root test. The regression including a drift variable produces a p-

value for the drift variable lower than 0.1. Hence, if one considers that both variables have a deterministic drift under the null hypothesis, the hypothesis that both variables are integrated of order one is clearly rejected in Table 1. The null hypothesis of a unit root without a drift is also rejected at the 10% significance level for the wholesale price. The *p*-value for the farm price when there is no drift in the equation is however greater than acceptable significance levels. Based on the reported evidence, the analysis in the next section assumes that the variables are stationary.

3. A Preliminary investigation of potential non-linearities in price transmission

Let P_t and F_t denote the wholesale and farm prices respectively at period t $\left(t=1,\ldots,T\right)$. The variables H_{t-1} and S_t represent the end-of-period $t-1$ inventory level and sales in period *t*, respectively. Let lower-case letters denote the logarithmic transformation of the variables. In the spirit of linear-quadratic inventory models (*e.g.*, West, 1995), we assume that inventory costs are increasing in the difference between the end-of-period inventories and a target inventory which is a linear function of the current period's sales, *e.g.* $\gamma_0+\gamma_1 S_t$. The parameters γ_1 and γ_0 represent, respectively, the conditional and unconditional components of the target inventory equation.

Consider first a iso-elastic price transmission equation: $P_t=\overline{A}F_t^{\alpha_1+\alpha_2\left(H_{t-1}-\gamma_0-\gamma_1 S_t\right)}$, where $\overline{A}>0$ is a constant. Taking a logarithmic transformation on both sides of the equation yields the reduced form price transmission equation:

$$p_t=\alpha_0+\alpha_1 f_t+\alpha_2 f_t\left(H_{t-1}-\gamma_0-\gamma_1 S_t\right) \tag{1}$$

where $\alpha_0\equiv\ln\overline{A}$. Given marketing institutions in the Canadian chicken industry, the farm price in period *t* is predetermined given producers and processors bargain over the price about two periods before the marketing period actually starts. The inventory accumulation equation is $H_t = Q_t + H_{t-1} - S_t$ where Q_t represents industry's output. The end-of-period inventory is also predetermined at time t. Because industry output is determined before actual marketing decisions are made, the variable Q_t is also pre-determined from a time t perspective. However the demand for inventories and sales in period t may be determined jointly with the wholesale price. The existence of significant barriers to trade for chicken products in Canada implies that the wholesale price is determined by domestic market conditions and thus there exists a simultaneity issue in (1). One option to resolve the simultaneity issue would be to omit sales from (1), and thus assume that $\gamma_1 = 0$. The inventory target would then simply be a constant. Annual per capita consumption of chicken meat in Canada went from 22.3 kg in 1992 to 30.0 kg in 2003 (Agriculture and Agri-food Canada, AAFC). An increase in inventories is thus to be expected if they are used to smooth out fluctuations in demand, or prevent stocking-out when the overall demand for chicken products is increasing. Moreover, sales and inventories clearly trend together in Figure 3. Failing to account for this correlation between inventories and demand could bias the relationship between price transmission and inventories.

As usual when trying to model non-linearity, the challenge is to capture the precise nature of the non-linearity without over-fitting the data. The iso-elastic functional form behind (1) is one of many possible relationships between prices, sales and inventories. The first step will thus involve investigating potential non-linearities in price transmission using Hamilton (2001, 2003)'s flexible nonlinear inference framework.

Hamilton's procedure entails estimating a nonlinear regression model of the form: $y_t = \mu(\mathbf{z}_t) + \varepsilon_t$; where y_t is the dependent variable, $\mathbf{z}_t$ is a vector of independent variables of dimension $T \times k$ and ε_t is a normally distributed random error term with zero mean and variance

σ^2. The empirical strategy is to view the function $\mu(\mathbf{z}_t)$ as the outcome of random fields. For a given non-stochastic vector $\mathbf{z}$, the function $\mu(\mathbf{z})$ is assumed to be normally distributed with mean $\delta_0 + \boldsymbol{\delta}_1\mathbf{z}_t$ and variance λ^2. The regression equation reduces to a standard linear regression $\left(y_t = \delta_0 + \delta_1\mathbf{z}_t + \varepsilon_t\right)$ when the variance of the random field is zero. Conversely, the price transmission equation can substantially deviate from a linear regression model if the value of λ is large.

The estimation of the random fields proceeds through an algorithm to search over the parameters that characterize the variability of the function $\mu(\mathbf{z})$. Hamilton (2001) assumes that two random realizations, $\mathbf{z}_1$ and $\mathbf{z}_2$, are uncorrelated if they are sufficiently far apart. Specifically, the correlation is zero when $0.5\left(\sum_{j=1}^{k} g_j^2\left(z_{j1} - z_{j2}\right)^2\right)^{0.5} > 1$, where the parameters $\mathbf{g} = \left[g_1 \quad \dots \quad g_j \quad \dots \quad g_k\right]$ govern the variability of the nonlinear function as the $\mathbf{z}$ vary. The flexibility of the approach comes from the previous functional form assumed to guide the variability of the random field. In the present case, the regression equation can be rewritten as:

$$y_t = \delta_0 + \boldsymbol{\delta}_1\mathbf{z}_t + \lambda m\left(\mathbf{g}\mathbf{z}_t\right) + \varepsilon_t \tag{2}$$

where $m(\cdot)$ is the stochastic process that characterizes the conditional expectation. The parameters in (2) are estimated with maximum likelihood techniques. The non-negligible advantage of the flexible non-linear framework is that it allows for a direct test of the null hypothesis that the relation between $\mathbf{z}$ and y is linear. This amounts to testing whether λ^2 is different from zero with a Lagrange Multiplier (LM) test holding the coefficients in **g** at a value proportional to their standard deviation.

Given that instrumental variable estimation techniques have yet to be developed for flexible non-linear models, we use the ratio of inventories to sales $\left(H_{t-1}/S_t\right)$ as an independent variable[7] in the price transmission equation to lessen the potential correlation between sales and the error term. The dependent variable will be logarithmic transformation of the wholesale price $\left(p_t\right)$ and $\mathbf{z}_t \equiv \left[f_t \quad H_{t-1}/S_t\right]$.

The estimates of the model are derived from the maximization of a log-likelihood function and the standard errors are the usual asymptotic estimates. They are reported in the second column of Table 2. Note that the error term is standardized such that $\lambda \equiv \sigma \cdot \omega$. The chi-squared version of the LM non-linearity test is used because it has good properties in small samples (Hamilton, 2001). The null hypothesis of a linear model is soundly rejected. The test statistic is 78.06 and is larger than the chi-squared statistic with one degree of freedom (*p-value* less than 0.001).

The parameters of the linear component in (2) are statistically significant. To offer a comparison between the Hamilton framework and a standard linear model of price transmission with f_t and H_{t-1}/S_t as independent variables, Table 2 also reports the OLS estimates of a linear model. The price transmission elasticity of the strictly linear model is 1.062. The coefficient of the farm price in the linear component of (2) is higher, but also has a large standard error. The coefficients for the ratio of inventories to domestic sales in the linear component of (2) and the linear price transmission equation are of similar magnitude and economic interpretation. More importantly, the parameters of the non-linear component in (2) and the estimate of σ and ω are quite large compared to their standard error, thus indicating a statistically significant form of non-linearity in price transmission. While the statistical evidence about non-linearity is quite strong, it is difficult to gauge the nature of this non-linearity simply by analyzing the coefficients in Table 2.

To characterize the non-linearity in the price transmission model, Figure 5 plots the natural log of the predicted wholesale price as function of the natural log of the farm price for three different values of the ratio of inventories to domestic sales (the sample average and the sample average plus/minus twice the standard error of the ratio). The first thing to note is that a constant price transmission elasticity (given the ratio of inventories to domestic sales) is clearly rejected by the non-linear framework. The price transmission elasticity is almost everywhere increasing in the level of the farm price. Moreover, the lower is the ratio of inventories to domestic sales, the higher is the price transmission elasticity, *ceteris paribus*. Figure 5 suggests a specific functional form for price transmission which will be investigated in the next section.

4. Investigating the price transmission elasticity

The evidence in the previous section is indicative of non-linearity, but it would be nice to have a more precise idea of the influence of inventories on price transmission. This could be achieved, for example, if more specific assumptions with respect to inventory behaviour are introduced in the model. One set of assumptions involves the target inventory equation discussed at the beginning of the previous section.

Assuming that $H_{t-1} = \gamma_0 + \gamma_1 S_t$, the evidence in Figure 5 suggests a functional form for the price transmission equation resembling a semi-logarithmic form: $P_t = \exp\left\{\alpha_0 + \alpha_1 F_t + \alpha_2 f_t \left(H_{t-1} - \gamma_0 - \gamma_1 S_t\right)\right\}$. Recalling that a lower-case letter denotes the logarithmic transformation of a variable, the price transmission equation can be rewritten as:

$$p_t = \alpha_0 + \alpha_1 F_t + \alpha_2 f_t \left(H_{t-1} - \gamma_0 - \gamma_1 S_t\right) + u_t \tag{3}$$

where u_t is a random error term with mean zero and constant variance.

The coefficient α_1 measures the direct impact of the farm price on the percentage change in the wholesale price, not accounting for the potential influence of inventories. The coefficient α_2 measures the combined impact of inventories and a percentage change in the farm price on the percentage change in the wholesale price.

The price transmission elasticity in (3) is:

$$\eta \equiv \left(\partial p_t / \partial F_t\right) F_t = \alpha_1 F_t + \alpha_2 \left(H_{t-1} - \gamma_0 - \gamma_1 S_t\right) \tag{4}$$

It is clear in (4) that η is: *i*) a linearly increasing function of the farm price; and *ii*) that deviations between inventories and the target level only have an impact on the intercept of the price transmission equation. These two observations are consistent with the evidence presented in Figure 5. However, estimating (3) poses a challenge for inference because of potential collinearity between the farm price and the logarithmic transformation of the farm price.

As mentioned in the preceding section, there is a potential correlation between S_t and u_t and thus equation (3) is estimated using the Generalized Method of Moments (GMM) procedure. It entails setting the sample moment conditions of the model as close to zero as possible using a quadratic loss function defined by the product of the sample moment conditions and a weighting matrix. In the present case, the weighting matrix is obtained using the residuals of the Nonlinear 3 Stage Least Squares (N3SLS) matrix with a Bartlett kernel with the truncation parameter of the bandwidth selected according to the formula $l = 4\left(T/100\right)^{2/9}$. There is very little guidance in the GMM literature to select the instruments in finite samples, but it is known that asymptotic efficiency may be inversely related to the number of instruments (Imbens, 1997). Hence, the instruments will be sales lagged one and two periods and the farm price as well as its logarithmic transformation.[8]

Table 3 presents the GMM estimates of the price transmission equation in (3). All the estimated coefficients are statistically different than zero. Because there are more instruments than sample moment conditions in the model, the GMM approach can use over-identifying restrictions to test the consistency of the GMM estimator. The *J*-test for over-identifying restrictions does not reject the null hypothesis that the model is correctly specified. The test statistic (7.01) is below the critical value (with three degrees of freedom) at the 5 percent significance level.[9]

The estimate of α_1 is 0.758 and significantly different than zero at the 5 percent significance level. The estimate of α_2 is 0.049 and significant at the 5 percent level. The sign of the coefficient α_2 suggests that inventories above the target level will increase the magnitude of price transmission. The estimate of the target inventory (γ_1) is 72 percent of domestic sales.

When lagged inventories and sales are evaluated at their sample mean, the price transmission elasticity is 1.21 (with standard error 0.12). Figure 6 presents the pattern of price transmission elasticities for the non-linear structural model in (3) and the log-linear model of price transmission. It is quite clear that the log-linear model under-estimates the price transmission elasticity between the wholesale and farm prices when compared to the non-linear model. Over the entire sample, the price transmission elasticity under the semi-log is smaller than the point estimate of the constant elasticity model in only 18 percent of cases.

6. Concluding remarks

Increased concentration in agri-food supply chains combined with recent advances in time series econometrics has stimulated significant research efforts to detect asymmetric price transmission in agri-food supply chains. This paper contributes to the literature on asymmetric price transmission by investigating the influence of inventories in explaining non-linearities in the relationship between farm and wholesale prices. Marketing mechanisms and the existence of production quotas at the farm level in the Canadian chicken industry imply the farm price and output at the farm level are determined before domestic demand is known. Hence, there is a role for inventories in smoothing the impacts of unanticipated shocks in demand and supply.

Most of the empirical literature on price transmission analyzes asymmetry in the speed of transmission. Generally, a negative or positive price shock at one level of the supply chain will cause a proportional price change in the upstream and/or downstream markets, but the equilibrium will be reached at a different pace depending on whether the shock is positive or negative. Conversely, the idea in this paper is that the relationship between prices may be conditional on other factors. Borrowing from the macroeconomics literature on linear-quadratic inventory models, we specified a price transmission equation between farm and wholesale prices which is function of deviations between actual inventories and a target inventory. The flexible non-linear inference framework of Hamilton (2001, 2003) is used to investigate potential non-linearities. The procedure suggests that the price transmission elasticity is increasing in the farm price and decreasing in the ratio of inventories to sales.

The flexible inference framework suggests that the price transmission elasticity is an increasing function of the farm price and is also function of inventories. We propose a semi-log equation to investigate further the role of inventories on price transmission. We implement a

GMM procedure to account for potential correlation between domestic sales and the wholesale price. We found that price transmission is lower (higher) when inventories are below (above) a target which is function of domestic sales.

While non-linear econometric tools have been successful in pointing out potential asymmetries in price transmission, the usefulness of these models is limited for policy purposes because they do not identify the source of asymmetry. Future research endeavours in price transmission should focus on the estimation of structural models. Policy makers need to have a better idea of the impacts of menu costs of changing prices, non-competitive behaviour, inventory costs, etc. on price transmission to evaluate whether policy should be used to correct potential market failures.

6. References

Abbassi, A. and J-P. Gervais. 2010. Evaluating Reforms in Canadian Chicken Marketing Mechanisms Using a Linear-quadratic Inventory Model. *Journal of Agricultural and Food Industrial Organization* 8: Article 1.

Abdulai, A. 2002. Using Threshold Cointegration to Estimate Asymmetric Price Transmission in the Swiss Pork Market. *Applied Economics* 34: 679-687

Azzam, A. 1999. Asymmetry and Rigidity in Farm-Retail Price Transmission. *American Journal of Agricultural Economics* 81: 525-533.

Ben-Kaabia, M. and J. M. Gil. 2007. Asymmetric Price Transmission in the Spanish Lamb Sector. *European Review of Agricultural Economics* 34: 53-80.

Blanchard, O. 1983. The Production and Inventory Behavior of the American Automobile Industry. *Journal of Political Econom*y 91: 365-400.

Borenstein, S., and A. Shepard. 2002. Sticky Prices, Inventories, and Market Power in Wholesale Gasoline Markets. *The RAND Journal of Economics* 33: 116-139.

Borenstein, S., C. Cameron, and R. Gilbert. 1997. Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes. *The Quarterly Journal of Economics* 112: 305-339.

Carman, H.F. and R.J. Sexton. 2005. Supermarket Fluid Milk Pricing Practices in the Western United States. *Agribusiness* 21: 509-530.

Chavas, J-P., and A. Mehta. 2004. Price Dynamics in a Vertical Sector: The Case of Butter. *American Journal of Agricultural Economics* 86: 1078-1093.

Davidson, R. & J.G. MacKinnon, 1993, *Estimation and Inference in Econometrics,* Oxford University Press, New York, NY.

Deaton, A., and G. Laroque. 1992. On the Behaviour of Commodity Prices. *Review of Economic Studies* 59: 1-23.

Fousekis, P. 2008. Further Results on Assymetry in Farm-Retail Price Transmission under Spatial Monopoly. *Journal of Agricultural and Food Industrial Organization* 6(1): Article 7. Available at: http://www.bepress.com/jafio/vol6/iss1/art7

Frey, G., and M. Manera. 2007. Econometric Models of Asymmetric Price Transmission. *Journal of Economic Surveys* 21: 349-367.

Fulton, M. and Y. Tang. 1999. Testing the Competitiveness of a Multistage Food Marketing System: The Canadian Chicken Industry. *Canadian Journal of Agricultural Economics* 47: 225-250.

Gervais, J-P., S. Devadoss. 2006. Estimation Bargaining Strengths of Canadian Chicken Producers and Processors Using a Bilateral Monopoly Framework. *Agribusiness* 22: 159-173.

Gervais, J-P., K. Guillemette, and R. Romain. 2007. Output and Price Determination in the Canadian Chicken Industry: Which Should Come First? *Canadian Journal of Agricultural Economics* 55: 255-273.

Gervais J-P. 2010. Disentangling Non-linearities in the Long- and Short-run Price Relationships: An Application to the U.S. Hog/Pork Supply Chain. *Applied Economics*: Forthcoming.

Goodwin, B. K., and M. T. Holt. 1999. Asymmetric Adjustment and Price Transmission in the U.S. Beef Sector. *American Journal of Agricultural Economics* 81: 630-637.

Hamilton, J. D. 2001. A Parametric Approach to Flexible Nonlinear Inference. *Econometrica* 69: 537–573.

Hamilton, J. D. 2002. On the Interpretation of Cointegration in the Linear-Quadratic Inventory Model. *Journal of Economic Dynamics and Control* 26: 2037-2049.

Hamilton, J. D. 2003. What is an Oil Shock? *Journal of Econometrics* 113: 363–398.

Houck, J. P. 1977. An Approach to Specifying and Estimating Non-reversible Functions. *American Journal of Agricultural Economics* 59: 570-572

Huff, K., K. D. Meilke, and R. Amedei. 2000. Canada–United States Chicken Trade: A Re-evaluation. *Canadian Journal of Agricultural Economics* 48: 421-432:

Imbens, G.W. 1997. One-Step Estimators for Over-Identified Generalized Method of Moments Models. *Review of Economic Studies* 64: 359-383.

Kesavan, S. V. Gaur., A. Raman. 2010. Do Inventory and Gross Margin Data Improve Sales Forecasts for US Public Retailers? *Management Science* 56 : 1519–1533

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.

Lass, D. A. 2005. Asymmetric Response of Retail Milk Prices in the Northeast Revisited. *Agribusiness* 21: 495-508.

Lloyd, T. A., S. McCorriston, C. W. Morgan, and A. J. Rayner. 2006. Food Scares, Market Power and Price Transmission: the UK BSE Crisis. *European Review of Agricultural Economics* 33: 119-147.

Maddala, G. S., and I-M. Kim. 1998. *Unit Roots, Cointegration and Structural Change*. Cambridge University Press..

McCorriston, S., C. W. Morgan, and A. J. Rayner. 2001. Price Transmission: the interaction between Market Power and Returns to Scale. *European Review of Agricultural Economics* 28: 143-159.

Meyer, J., and S. von Cramon-Taubadel. 2004. Asymmetric Price Transmission: A Survey *Journal of Agricultural Economics* 55: 581-611.

Miller, D. J., and M. L. Hayenga. 2001. Price Cycles and Asymmetric Price Transmission in the U.S. Pork Industry. *American Journal of Agricultural Economics* 83: 551-562.

Parker, C., E, Paparoditis and D. N. Politis. 2006. Unit Root Testing via the Stationary Bootstrap. *Journal of Econometrics* 133: 601-638.

Rude, J. and J-P. Gervais. 2006. Tariff Rate Quota Liberalization: The Case of World Price Uncertainty and Supply Management. *Canadian Journal of Agricultural Economics* 54: 29-51.

Serra, T., and B. K. Goodwin. 2003. Price Transmission and Asymmetric Adjustment in the Spanish Dairy Sector. *Applied Economics* 35: 1889–1899.

Von Cramon-Taubadel, S. 2001. Estimating Asymmetric Price Transmission with the Error Correction Representation: An Application to the German Pork Market. *European Review of Agricultural Economics* 25: 1-18.

Ward, R.W. 1982. Asymmetry in Retail, Wholesale and Shipping Point Pricing for Fresh Vegetables. *American Journal of Agricultural Economics* 62: 205-212.

West, K. D. 1995. Inventory Models. Published in *Handbook of Applied Econometrics*. Edited by M. Pesaran and M. Wickens, Vol I, Macroeconomics, Basil Blackwell, Oxford.

Wohlgenant, M. K. 1985. Competitive Storage, Rational Expectations, and Short-Run Food Price Determination. *American Journal of Agricultural Economics* 67:739-48.

Wohlgenant, M.K. 2001. Marketing Margins: Empirical Analysis. In *Handbook of Agricultural Economics*, edited by B. Garnder and G. C Rausser, Vol. 1B: 933-970.

Xia, T. 2009. Asymmetric Price Transmission, Market Power, and Supply and Demand Curvature. *Journal of Agricultural & Food Industrial Organization*: Vol. 7 : Iss. 1, Article 6. Available at: http://www.bepress.com/jafio/vol7/iss1/art6 DOI: 10.2202/1542-0485.1261

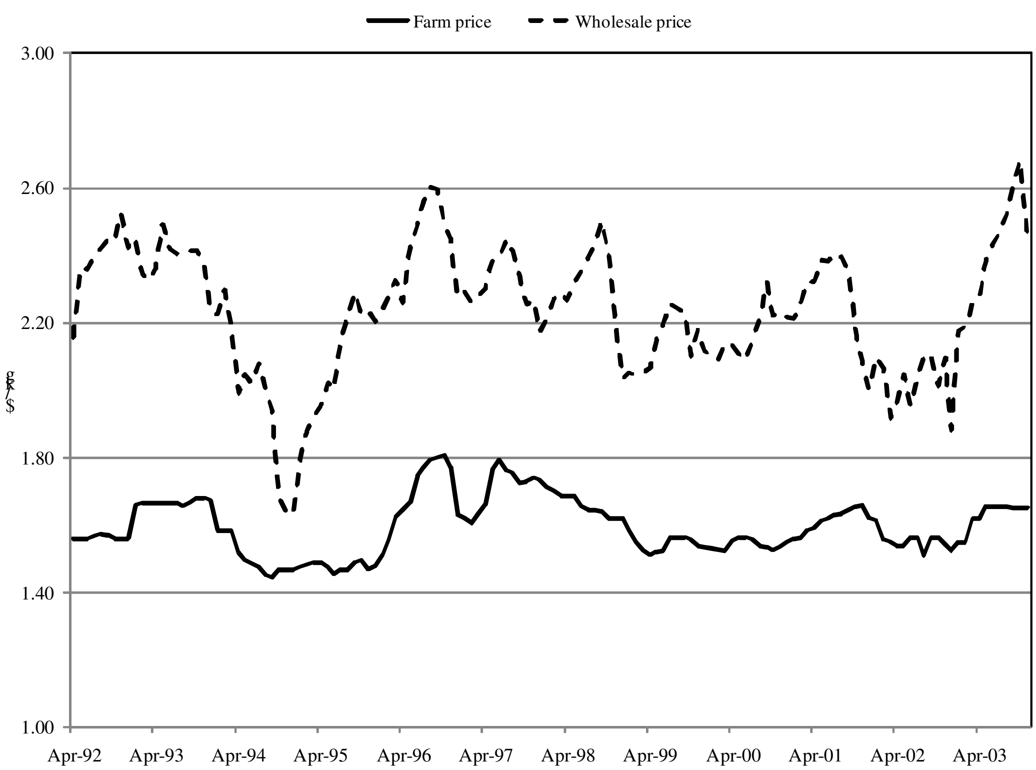

Figure 1. Monthly farm and wholesale prices in Ontario, April-1992 to Nov-2003.

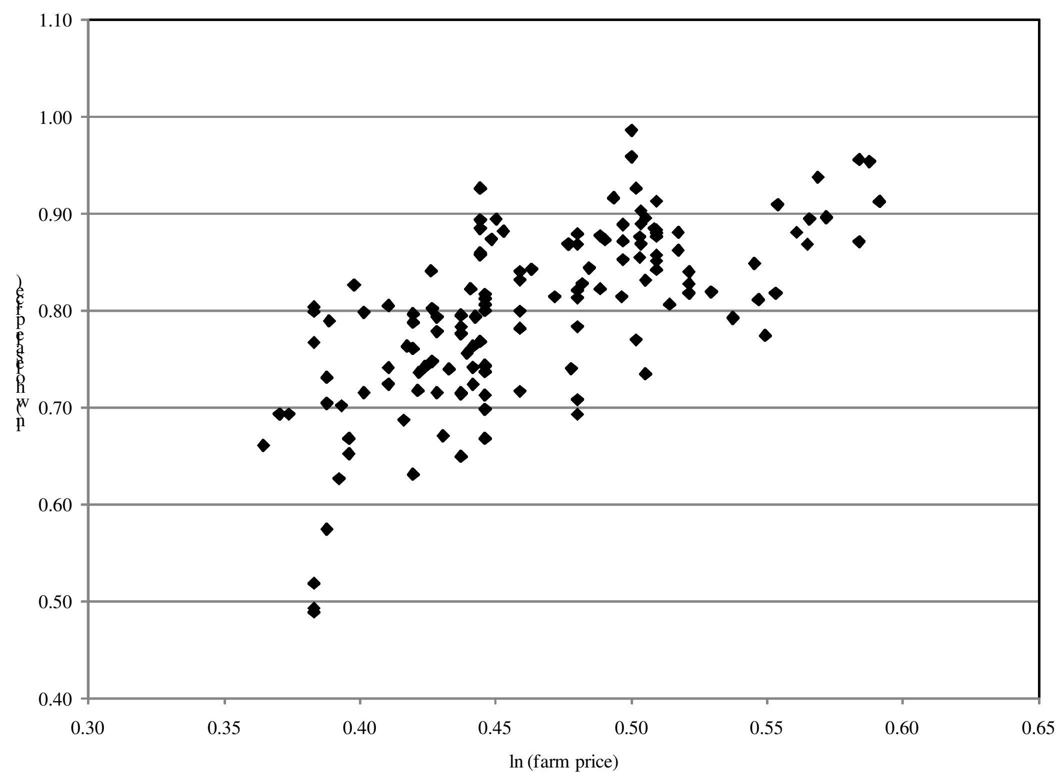

Figure 2. Correlation between Ontario farm and wholesale prices, April-1992 to Nov-2003.

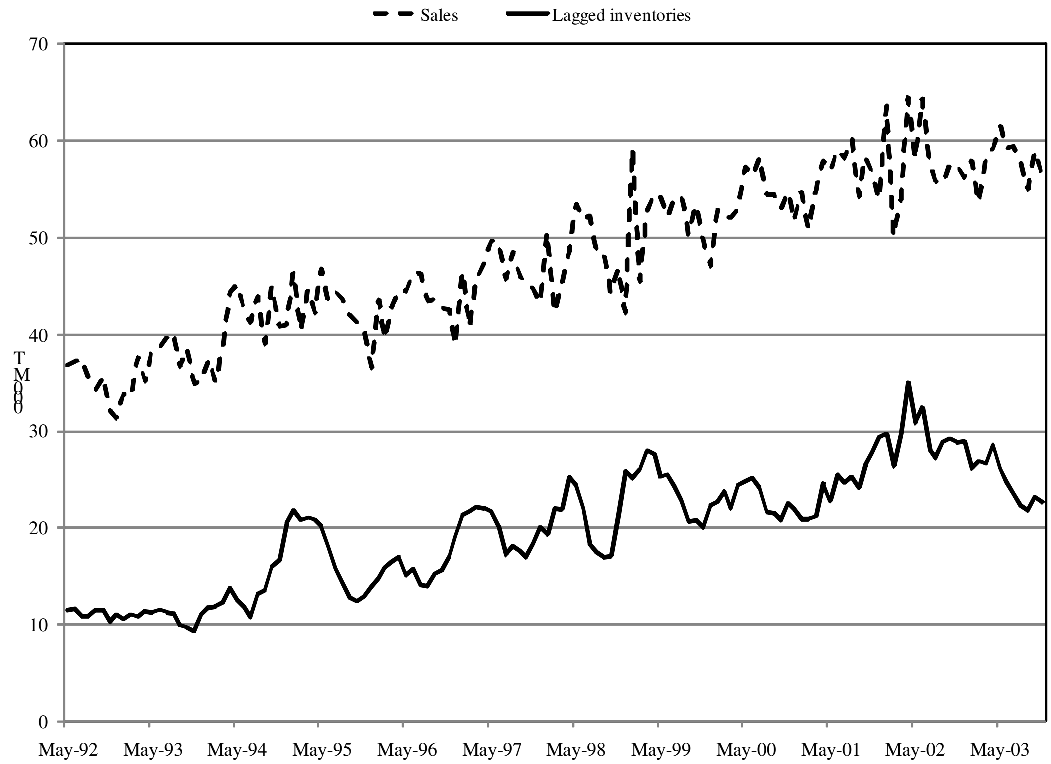

Figure 3. Monthly sales and lagged inventories, April-1992 to Nov-2003.

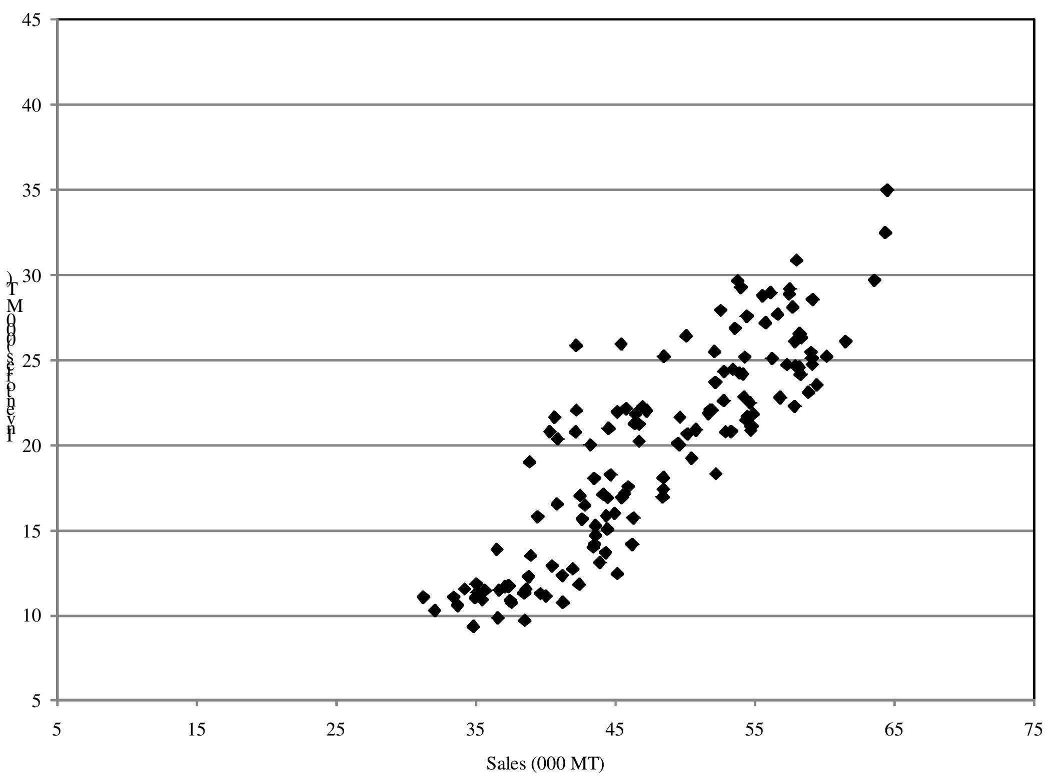

Figure 4. Correlation between sales and lagged inventories, April-1992 to Nov-2003.

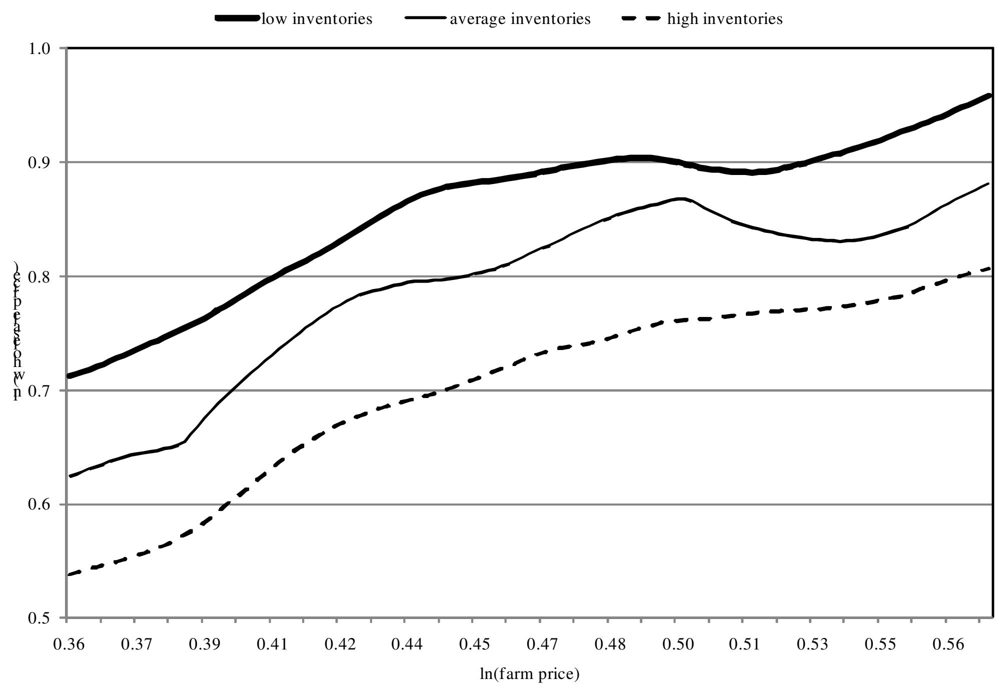

Figure 5. Predicted price transmission elasticities conditional on different ratios of inventories to sales

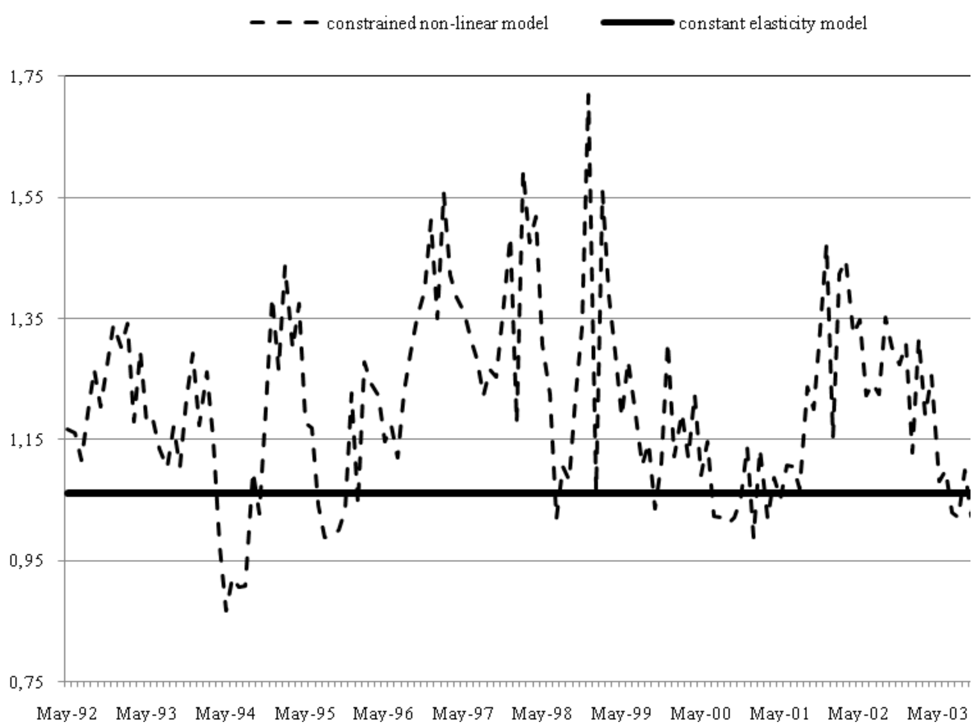

Figure 6. Predicted price transmission elasticities of the non-linear, log-linear and threshold models

Table 1. Unit root bootstrap results

Variables	*p-value* for the null hypothesis of a unit root	
	with drift	without drift
Farm price	0.012	0.229
Wholesale price	0.001	0.085
Inventories	0.009	0.347
Sales	0.000	0.033

Note: The natural logarithmic transformation of the prices was used. The drift for the farm price was significant at 6%

Table 2. Estimates of the price transmission equation using Hamilton flexible inference framework and a OLS estimator

	Hamilton – non-linear model		OLS – linear model	
Variables	Estimate	*p*-value	Estimate	*p*-value
Linear component				
Constant	0.405 (0.157)	0.005	0.479 (0.053)	0.000
Farm price	1.220 (0.304)	0.000	1.062 (0.092)	0.000
Ratio inventories / sales	-0.503 (0.123)	0.000	-0.432 (0.063)	0.000
Non-linear component				
Farm price	3.085 (1.916)	0.054		
Ratio inventories / sales	0.978 (0.314)	0.001		
σ	0.046 (0.003)	0.000		
ω	17.01 (3.650)	0.000		

Note: The adjusted coefficient of determination for the OLS regression $(\bar{R}^2)$ is 0.596.

Table 3. GMM estimates of the price transmission model

Parameters	Estimate (standard error)	*p*-value
α_0	-0.410	0.001
	(0.123)	
α_1	0.758	0.000
	(0.077)	
α_2	0.049	0.016
	(0.022)	
γ_0	-14.670	0.000
	(1.696)	
γ_1	0.720	0.000
	(0.035)	

Endnotes

[1] Several theoretical studies (e.g. Borenstein et al., 1997; Azzam, 1999; Xia, 2009) highlight the role of imperfect competition in markets on asymmetric price transmission.

[2] The literature on supply management in the chicken industry generally focused on analyzing either the economic performance of domestic marketing institutions (*e.g.*, Fulton and Tang, 1999; Gervais and Devadoss, 2006; Gervais, Guillemette and Romain, 2007) or the competitiveness of the industry under broad globalization pressures (*e.g.,* Huff, Meilke, and Amedei, 2000; Rude and Gervais, 2006).

[3] Frey and Manera (2007) provide a more detailed categorization of asymmetric price transmission by focusing on the properties of the empirical models used to reveal asymmetry.

[4] Miller and Hayenga (2001) appeal to the existence of menu costs and asymmetric inventory adjustment costs to explain changes in firms' pricing strategies; but never formally introduced inventories in the price transmission relationship. Other studies that appeal to inventories to explain APT without explicitly accounting for them include Kinnucan and Forker (1987), von Cramon-Taubadel (2001), Abdulai (2002).

[5] Processors play an important role in the management of chicken inventories given the institutional features of the Canadian poultry supply chain. As such, they are likely to have a significant impact on APT through the inventory channel. In addition, Gervais and Devadoss (2006) showed that chicken processors had greater bargaining power than chicken producers. Recently, Xia (2009) extended the analysis of Azzam (1999) and Fousekis (2008) to study asymmetries in the magnitude of price transmission. Xia (2009) found that asymmetries in the magnitude of wholesale-farm margins can be jointly due to buyer power in the farm market and the curvature of the farm supply.

[6] Domestic sales do not account for imports because monthly import data is thought to be unreliable. Trade of chicken products is controlled by a Tariff Rate Quota (TRQ) that sets a minimal (zero for U.S. products) tariff on imports below the minimum access commitment (currently set at 7.5% of the previous year's production) and a very large (prohibitive) tariff on imports exceeding the minimum access commitment. Because the TRQ acts as a *de facto* import quota, the demand schedule that domestic processors face is the residual demand schedule once within-quota imports are accounted for.

[7] Note that in the context of the linear-quadratic inventory model, this ratio is consistent with the parameter γ_0 constrained to zero.

[8] Endogeneity between sales, inventories and margins is well known (e.g. Kesavan, Gaur, and Raman, 2010). And because of the institutional framework of the chicken industry we expect a one period lagged end-of inventory to also be endogenous because of high serial correlation with current inventories. It prevents us to consider the one lagged value of inventories as exogenous.

[9] The degrees of freedom equal number of equations × number of instruments - number of parameters in the system. It must be noted however that the *J*-test can have low power in small samples (Davidson and MacKinnon, 1993).