Evaluating Reforms in Canadian Chicken Marketing Mechanisms Using a Linear-Quadratic Inventory Model

Abdessalem Abbassi, Laval University
Jean-Philippe Gervais, North Carolina State University

Available at: https://works.bepress.com/abdessalem_abbassi/2/
Evaluating Reforms in Canadian Chicken Marketing Mechanisms Using a Linear-Quadratic Inventory Model

Abdessalem Abbassi, Laval University
Jean-Philippe Gervais, North Carolina State University

Recommended Citation:
Available at: http://www.bepress.com/jafio/vol8/iss1/art1
DOI: 10.2202/1542-0485.1263

©2010 Berkeley Electronic Press. All rights reserved.
Evaluating Reforms in Canadian Chicken Marketing Mechanisms Using a Linear-Quadratic Inventory Model

Abdessalem Abbassi and Jean-Philippe Gervais

Abstract

Marketing institutions in supply managed industries are evolving due to broad globalization pressures. The output and sales decisions of chicken processing firms under two different pricing mechanisms are modeled using a linear-quadratic inventory model. Decision rules lead to structural equations that relate output and sales to their own lagged values, lagged inventories and lagged prices and cost indicators. A Generalized Method of Moments (GMM) estimator is applied to the system of equations. The null hypotheses no adjustment costs in processing and no role for inventories in marketing are rejected. We simulate the impacts of reforming the chicken pricing mechanism, moving from producers vs. processors bargaining to a formula-based price (referred to as “cost-plus”). Output in the industry is higher under the bargaining pricing system mostly because processors pay a lower price than under the “cost-plus” mechanism. Simulations reveal that producers' expected profits are lower on average under the bargaining system than under “cost-plus.” Moreover, the “cost-plus” system reduces the variability of profits.

KEYWORDS: supply management, Canadian chicken industry, linear-quadratic inventory model, price bargaining

Author Notes: We would like to thank Bruno Larue and seminar participants at the University of Saskatchewan and the GAEL research center in Grenoble for providing helpful comments. We are also grateful for the comments of two anonymous reviewers. All remaining errors are our own.
1. Introduction

The cornerstone of Canadian agricultural policy for the poultry and dairy sectors is supply management. Both sectors rely on production controls (quotas) and border measures to support the price paid to producers. For supply management to be effective from the producers’ perspective, it requires a compulsory horizontal integration of producers (through a marketing board) and trade policies to prevent entry of foreign products. The performance of these systems has been more heavily scrutinized in recent years because of broad globalization pressures in the agri-food sector. Many fear that trade liberalization plans will negatively impact Canadian marketing institutions for poultry and dairy.

The purpose of this paper is to evaluate the welfare implications of reforming domestic marketing institutions for Canadian chicken producers. A linear-quadratic inventory model is developed to analyze output decisions and pricing mechanisms. Chicken production at the farm level in each province has been determined using a bottom-up approach since 1995. Chicken processors survey market opportunities about 12 weeks before actual farm production is to begin and relay their demand to producers’ marketing boards in each province. Farm output is set for a quota allocation period of eight weeks. The production quotas in each province are adjusted to sum to the quota allocation at the national level, as determined by Chicken Farmers of Canada (CFC). Whether the current output decision rule is a true bottom-up system is debatable because processors’ requests in a given quota allocation period are often scaled down by CFC. However, buyers do have some input on the chicken farm production level.

From 1992 up until early 2003, farm prices were set through negotiations between producers’ marketing boards and processors in each province. Negotiated prices in the province of Ontario (the largest producing province) were generally used as a basis for the price negotiations in the other provinces. The Ontario chicken marketing board and representatives of the processing industry met at regular intervals to negotiate the price that was to be paid by processors to all producers over a quota period. When an agreement on live chicken prices could not be reached within a reasonable amount of time (about four to six weeks before the beginning of the corresponding quota period), an arbitration process selected one of the parties’ final offer. Starting in May 2003, the chicken pricing process in Ontario was changed to a formula-based live price negotiated once a year. It includes three producers’ cost components: 1) feed; 2) chick; and 3) a fixed producer margin. This formula is often referred to as a “cost-plus” pricing system. The live chicken price is now set about sixteen weeks in advance, and holds for two quota periods. The producers’ margin component is determined once every six quota periods. The feed component is based on the average feed price posted
by independent feed mills in the two quota allocation periods that precede the price determination stage.

It is not entirely clear what were the exact motivations behind the reforms in chicken pricing. If agents are risk neutral, the transition from the bargaining model to the “cost-plus” mechanism involves a simple comparison of expected net returns under the two scenarios. Anecdotal evidence drawn from the Ontario Chicken producers’ newsletters (CFO, 2002) suggests that this was the primary motivation. However, it is difficult to argue that risk was not an important driver of the reform. Under the assumption of risk aversion, the welfare ranking involves comparing the trade-offs between expected net returns and variability. For example, if chicken producers favor the “cost-plus” scheme over the bargaining mechanism, the gains of fixing farm prices earlier in the marketing process must outweigh the risk that the farm price will not reflect market conditions at the production stage. The objective of the paper is to precisely analyze the extent of the shifts in risk and expected returns of chicken producers following the marketing reform.

The literature on supply management has generally focused on analyzing the welfare implications of supply controls from a domestic perspective (e.g., Veeman, 1982; Schmitz, 1983; Fulton and Tang, 1999, Gervais and Devadoss, 2006) or in a trade context (e.g., Vercammen and Schmitz, 1992; Barichello, 1999; Larue et al., 1999, Huff et al., 2000; Rude and Gervais, 2006). Gervais, Guillemette and Romain (2007) have analyzed the efficiency of the Canadian chicken industry’s pricing mechanisms. They found that bargaining generates higher expected utility for producers over the “cost-plus” system for reasonable degrees of risk aversion. In fact, risk aversion needed to be quite significant for producers to support reforming the pricing mechanism. This result runs counter to anecdotal evidence as well as basic economic intuition. The Canadian chicken industry is a relatively stable industry which is not exposed to large market fluctuations due to high trade barriers. However, they omitted to consider dynamics in their model and left out altogether the issue of inventories. Our analysis investigates the role of inventories in determining market outcomes for the industry.

Figures 1 and 2 present output and sales in each quota allocation period between 1995 and the end of 2002. Figure 1 clearly illustrates the growth of the chicken industry due to a shift in Canadian consumers’ preferences and demographics (AAFC, 2006). Figure 2 illustrates the detrended output and sales series. Sales are slightly more volatile than output with a relative variance of 19.4 versus 15.9 for output.
Figure 1. Production and sales in the Canadian chicken industry per quota allocation period.

Figure 2. Detrended production and sales in the Canadian chicken industry per quota allocation period.
Figure 3 illustrates the ratio of inventories over sales. The volatility of the ratio suggests that inventories may have an important role in balancing unexpected changes in demand and supply for the supply management system.\(^1\) The ratio increased significantly between quota periods A-33 and A-49, which coincides with the period leading up to the changes in marketing mechanisms.

![Figure 3. Ratio of inventories over sales in the Canadian chicken industry per quota allocation period.](image)

The next section develops a theoretical model that replicates output, sales and pricing decisions in the Canadian chicken industry over the 1995-2002 period using a linear-quadratic inventory framework borrowed from the macroeconomics literature (e.g., West, 1995). The model yields tractable output and sales equations which are then used to estimate the structural parameters related to production, inventory and adjustment costs in the processing sector. A Generalized Method of Moments (GMM) estimator is used to account for simultaneity and non-linearity issues. We find strong evidence of significant output adjustment costs and statistically significant inventory target in the Canadian chicken industry.

The estimates of the structural parameters in the model are used in section four to simulate the impacts of reforming farm pricing mechanisms on the industry’s output and producers’ expected profits. The “cost-plus” system

\(^1\) Of course, the role of inventories in agri-food supply chains has been analyzed in a variety of other settings such as price transmission (e.g., Miller and Hayenga, 2001), industry cycles (e.g., Marsh, 1999; Hamilton and Kastens, 2000), and farm household behaviour (e.g., Renkow, 1990).
generates higher expected profits than the price bargaining mechanism. Moreover, profits are less variable under “cost-plus” and thus producers may unambiguously favor the latter marketing system. The introduction of inventories in our model resolves the paradox uncovered in Gervais, Guillemette and Romain (2007) who argued that producers needed to be strongly risk-averse to support the cost-plus system.

2. The Theoretical Model

This section develops a linear-quadratic inventory model for the Canadian chicken industry in the spirit of Blanchard (1982) and West (1995). The existence of a lag between output and sales decisions introduces an important distinction between the usual inventory models and the current analysis. The production lag yields dynamics that differ from the received literature on inventory behavior because processing firms face a different information set when making their sales and output decisions.

There are three main decision variables in the chicken industry: 1) chicken output; 2) chicken sales; and 3) chicken farm price. The sequence of decisions under each farm pricing mechanisms is summarized in Figure 4. It is important to note that the timing of output and sales decisions remain the same in both pricing systems. Output at the farm level is determined two quota periods before actual transactions between producers and processors occur. Processed chicken product sales are instantaneous in the sense that processors do not have to commit to a certain sales volume before knowing the retail demand for chicken. However, Figure 4 illustrates that output is predetermined when sales decisions are made. In panel 4a, the farm price is determined through a bargaining process between producers and processors. The price of chicken is set about six weeks before the beginning of the quota period. In panel 4b, the farm price is determined at the same time as output decisions, far in advance of the marketing period.

Let \( r \) denote the price of live chickens and \( C(Q, w) \) be the aggregate cost function of chicken producers which is function of eviscerated output in the industry (denoted \( Q \)) and a vector of input prices (denoted \( w \)). There are two important variable inputs in chicken production, namely chicks and feed. Assume that there are constant returns to scale in the production of live chickens.\(^2\) Let the subscript “\( t \)” denote the quota allocation period. Producers’ time \( t \) profits computed at \( t-2 \) under the price bargaining mechanism are:

\[
\pi_t\big|_{t-2} = r_t Q_t - C\left(Q_t, w_t\right) = r_t Q_t - w_t Q_t
\]  \hspace{1cm} (1)

\(^2\) This assumption is particularly helpful at the price bargaining stage where the allocation of surplus in the industry is function of average revenue at the wholesale level and (constant) average costs at the farm level.
where for simplicity the chick and feed cost components have been subsumed into the variable \( w \) assuming a constant feed conversion ratio. As mentioned in the introduction, output in each province is determined through negotiations between provincial marketing boards and processors, and the agreed production quotas in each province sum to the production quota at the national level. The process is referred to by the industry as a “bottom-up” approach: processors survey market opportunities at the retail level and relay their demands to producers. Output in each quota allocation period is set about 2 quota allocation periods prior to the beginning of a given quota period.

4a. Bargaining model of pricing

4b. Cost-plus pricing

Figure 4. Timing of decisions in Chicken marketing mechanisms
We assume that there are \( N \) identical processors that cannot exercise market power \textit{vis-à-vis} the retail sector\(^3\); hence they consider the wholesale price (denoted by \( p_t \)) as exogenous. Total output is the sum of each firm’s output, and because processors are assumed to be identical, we have that: \( Q_t = Nq_t \); where \( q_t \) is the output of an individual processor. Consider the behavior of a representative firm. Let lowercase letters represent firm specific variables while their industry counterparts are represented by capital letters. The end-of-period individual inventory holdings in period \( t \) (denoted \( i_t \)) are defined by the identity: 
\[
s_t = q_t - (i_t - i_{t-1}).
\]
Inventory costs follow Blanchard (1982) and are made of two components. There are costs of carrying inventories (which are increasing in the level of inventories) and costs associated with stocking out (which are decreasing in the level of inventories because higher inventories reduce the probability of stocking out). Inventory costs are thus assumed quadratic in the difference between inventories and the target level of inventory. The latter is defined as a linear function of next period’s sales; and thus inventory costs at time \( t \) are:
\[
0.5a(i_{t-1} - b_0 - b_1s_t)^2.
\]
Storage and handling costs are reflected by the parameter \( a \) while the parameters \( b_1 \) and \( b_0 \) represent, respectively, the conditional and unconditional components of the target inventory equation.

Live chicken procurement costs are \( r_tq_t \). The processing costs are quadratic and equal: \( 0.5cq_t^2 \), with \( c > 0 \). Finally, there are costs associated with changing production levels from one period to the next (\textit{e.g.}, due to labor turnover and training costs). These output adjustment costs are assumed to be quadratic, \( 0.5d(q_t - q_{t-1})^2 \), with \( d > 0 \). Profits of a processing firm in period \( t \) equal sale revenues \( (p_t, s_t) \) minus total costs, which are defined as the sum of procurement, processing, output adjustment and inventory costs, respectively:
\[
\pi_t^p = p_t s_t - r_tq_t - 0.5cq_t^2 - 0.5d(q_t - q_{t-1})^2 - 0.5a(i_{t-1} - b_0 - b_1s_t)^2
\]
(2)

Under the bargaining pricing method, uncertainty at time \( t-2 \) exists because the wholesale and farm prices at time \( t \) are unknown. Expectations are computed from a \( t-2 \) perspective to be consistent with the information provided in Figure 4

\(^3\) Fulton and Tang (1999) found evidence of departure from competitive pricing in the Canadian poultry industry. They are not however able to pinpoint the source of the market power. Endogenizing sales in the model would involve considerable complications because inventories can then be used for strategic reasons. Given the uncertainty surrounding the presence of market power in the downstream levels of the market, we proceeded with the assumption of perfectly competitive behavior in chicken processing.
Under the assumption of risk neutrality\textsuperscript{4}, each processor maximizes the discounted sum of expected profits in period $t-2$ by choosing its output requirement in period $t$ and sales in period $t-2$: \( \max J(\cdot) = \sum_{j=0}^{\infty} \beta^j E_{t-2} \left[ \pi_{t-2, j}^p \right] \) conditional on the information set \( \Omega_{t-2} = \{ q_{t-2}, q_{t-1}, s_{t-3}, i_{t-3}, p_{t-2}, w_{t-2} \} \). The parameter \( \beta < 1 \) is the discount factor.

Note that because output at time $t-2$ is predetermined, it should be clear that selecting the end-of-period inventories or sales at $t-2$ are equivalent decisions. Hence, the first-order condition determining sales (using the inventory accumulation identity) is:\textsuperscript{5}

\[
\frac{\partial J(\cdot)}{\partial i_{t-2}} = -p_{t-2} - ab_i \left( i_{t-3} - b_0 - b_i s_{t-2} \right) + \beta E_{t-2} \left[ p_{t-1} - a \left( 1 - b_i \right) \left( i_{t-2} - b_0 - b_i s_{t-1} \right) \right] = 0
\]

For notational convenience, define \( x_{t-2} \equiv \left( i_{t-3} - b_0 - b_i s_{t-2} \right) \) and \( \phi \equiv \beta b_i^{-1} \left( 1 - b_i \right) \).

The first-order condition in (3) can be rewritten as:

\[
x_{t-2} = -\left( ab_i \right)^{-1} p_{t-2} + \beta \left( ab_i \right)^{-1} E_{t-2} \left[ p_{t-1} \right] - \phi E_{t-2} \left[ x_{t-1} \right]
\]

which implies that the solution for \( x_{t-2} \) is:

\[
x_{t-2} = \left( ab_i \right)^{-1} \left( \beta \sum_{i=0}^{\infty} \left( -\phi \right)^i E_{t-2} \left[ p_{t-1+i} \right] - \sum_{i=0}^{\infty} \left( -\phi \right)^i E_{t-2} \left[ p_{t-2+i} \right] \right) + \phi E_{t-2} \left[ x_{t-2+T} \right] \quad (4)
\]

Using a transversality condition, \( \lim_{T \to \infty} \phi^T E_{t-2} \left[ x_{t-2+T} \right] = 0 \), the solution in (4) becomes:

\[
x_{t-2} = -\left( ab_i \right)^{-1} \sum_{i=0}^{\infty} \left( -\phi \right)^i E_{t-2} \left[ p_{t-2+i} \right] + \beta \left( ab_i \right)^{-1} \sum_{i=0}^{\infty} \left( -\phi \right)^i E_{t-2} \left[ p_{t-1+i} \right]
\]

(5)

Suppose the wholesale price follows an autoregressive process of order 1 such that: \( p_{t-1} = \mu_p + \rho_p p_{t-2} + \varepsilon_{t-1} \) where \( \varepsilon_{t-1} \) is an iid shock and \( \rho_p < 1 \). We can show that \( E_{t-2} \left[ p_{t-2+i} \right] = \left( 1 - \rho_p^i \right) \left( 1 - \rho_p \right)^{-1} \mu_p + \rho_p^i \rho_p p_{t-2} \) and \( E_{t-2} \left[ p_{t-1+i} \right] = \mu_p \left( 1 - \rho_p^{i+1} \right) \left( 1 - \rho_p \right)^{-1} + \rho_p^{i+1} \rho_p p_{t-2} \). Equation (5) can be rewritten as:

\textsuperscript{4} As mentioned in the introduction, the move from a bargaining framework to a “cost-plus” system to determine the price of live chickens is modifying the distribution of risk in the supply chain. However, relaxing the assumption of risk neutrality for processors introduces significant non-linearities in the decision rules that make the solutions non-tractable at the empirical stage.

\textsuperscript{5} It must be noted that once chicken products are stored, we implicitly assume that it is not possible to track the products individually. However, chicken products are perishable and accounting for time dimension in the micro-management of inventories could yield different solutions. The assumption that products lose their identity is made for convenience and because of data limitations.

http://www.bepress.com/jafio/vol8/iss1/art1
which can be rewritten using properties of geometric series and the assumption that $|\phi| < 1$:

$$x_{t-2} = \frac{\mu_p (\phi + \beta)}{ab_l (1 + \phi \rho_p)} - \frac{1 - \beta \rho_p}{ab_l (1 + \phi \rho_p)} p_{t-2}$$

(6)

Substituting for the definition of $x_{t-2}$ into (6) yields optimal sales at time $t - 2$:

$$s^*_{t-2} = \left[ -\frac{\mu_p (\phi + \beta)}{ab_l^2 (1 + \phi \rho_p) (1 + \phi)} + \frac{1 - \beta \rho_p}{ab_l^2 (1 + \phi \rho_p)} p_{t-2} \right] + \left[ b_1^{-1} (i_{t-3} - b_0) \right]$$

(7)

Once optimal sales have been determined, the end-of-period inventories are defined by: $i^*_t = i_{t-3} + q_{t-2} - s^*_{t-2}$. Since optimal sales at time $t - 1$ are function of $i_{t-2}$ and other exogenous variables (summarized by a vector $\Psi_{t-1}$), it is possible to anticipate sales at time $t - 1$: $s^*_{t-1} = f \left( i^*_t, \Psi_{t-1} \right)$, where the superscript + denotes an expected value and $f (\cdot)$ denotes how expectations are formed as a function of the variables in the information set. Similarly, the level of inventories can be anticipated with the inventory accumulation equation at time $t - 1$ because output is predetermined at that period (i.e., belongs in the information set): $i^*_{t-1} = i^*_{t-2} + q_{t-1} - s^*_{t-1}$. In turn, this leads to anticipated sales at time $t$:

$$s^*_{t-1} = f \left( i^*_t, \Psi_{t} \right)$$. While exact sales at time $t$ are unknown, the previous equation makes it clear that period $t$ sales do not depend on the output level at time $t$. Hence, the first-order condition that determines output at time $t$ from a $t - 2$ perspective is:

$$\partial J (\cdot) / \partial q_t = E_{t-2} \left[ -r_t - c q_t - d (q_t - q_{t-1}) \right]$$

$$+ \beta E_{t-2} \left[ p_{t+1} (\partial S_{t+1} / \partial q_t) - a (\partial i_t / \partial q_t - b_1 (\partial S_{t+1} / \partial q_t)) (i_t - b_0 - b_3 s_{t+1}) \right]$$

(8)

$$+ d (q_{t+1} - q_t) = 0$$

---

6 This condition implies that $\left( 1 - b_1 \right) < \beta^{-1} b_1$ if $b_1$ is less than 1. The conditional target of the inventory equation must be large enough to have a finite solution.
Using \((7)\), we have:

\[
E_{t-2}^{1}(s_{t+1}) = -\frac{\mu_p}{a} \phi (\phi + \beta) + \frac{1 - \beta \rho_p}{a} E_{t-2}^{1}(p_{t+1}) + b_1^{-1} \left( E_{t-2}^{1}(s_{t}) - b_0 \right)
\]

and thus \(\partial s_{t+1}^{*} / \partial q_{t} = \left( \partial s_{t+1}^{*} / \partial i_{t} \right) \left( \partial i_{t} / \partial q_{t} \right) = b_1^{-1}\) because \(\partial i / \partial q_{t} = \frac{\partial i_{t} / \partial q_{t}}{0} = 1\). We can rewrite the first-order condition in \((8)\) as:

\[
E_{t-2}^{1} \left[ -r_{t} - c q_{t} - d \left( q_{t} - q_{t-1} \right) \right] + \beta E_{t-2}^{1} \left[ b_1^{-1} p_{t+1} + d \left( q_{t+1} - q_{t} \right) \right] = 0
\]

\((9)\)

Define \(L\) as the lag operator. Equation \((9)\) can be rewritten as:

\[
E_{t-2}^{1} \left[ q_{t+1} \right] = \frac{\left( \beta d \right)^{-1} E_{t-2}^{1} \left[ r_{t} \right] - \left( b_1 d \right)^{-1} E_{t-2}^{1} \left[ p_{t+1} \right]}{1 - \left( \beta d \right)^{-1} \left( c + d \left( 1 + \beta \right) \right)L + \beta^{-1}L^2}
\]

\((10)\)

The term between brackets on the left hand-side of \((10)\) is a polynomial in \(L\). Define \(\lambda_{1}\) and \(\lambda_{2}\) as the roots of this polynomial function with \(\lambda_{1} + \lambda_{2} = \left( \beta d \right)^{-1} \left( c + d \left( 1 + \beta \right) \right) > 0\) and \(\lambda_{1} \lambda_{2} = \beta^{-1}\). The roots are:

\[
\lambda_{1} = \frac{c + d \left( 1 + \beta \right) - \sqrt{-4 \beta d^2 + \left( c + d \left( 1 + \beta \right) \right)^2}}{2 \beta d}
\]

\[
\lambda_{2} = \frac{c + d \left( 1 + \beta \right) + \sqrt{-4 \beta d^2 + \left( c + d \left( 1 + \beta \right) \right)^2}}{2 \beta d}
\]

\((11)\)

It is relatively straightforward to show that \(\left| \lambda_{1} \right| < 1\) and \(\left| \lambda_{2} \right| > 1\) which implies that we have a steady state equilibrium (Blanchard, 1983). Equation \((10)\) can be rewritten as:

\[
\left( 1 - \lambda_{1}L \right) \left( 1 - \lambda_{2}L \right) E_{t-2}^{1} \left[ q_{t+1} \right] = \left( \beta d \right)^{-1} E_{t-2}^{1} \left[ r_{t} \right] - \left( b_1 d \right)^{-1} E_{t-2}^{1} \left[ p_{t+1} \right]
\]

Using properties of geometric series and \(\lambda_{2} = 1/\left( \beta \lambda_{1} \right)\), the optimal output level is:

\[
q_{t}^{*} = \lambda_{1} q_{t-1} - \lambda_{1} d^{-1} \sum_{i=0}^{\infty} \left( \beta \lambda_{1} \right)^i E_{t-2}^{1} \left[ r_{t+i} \right] + \beta \lambda_{1} \left( b_1 d \right)^{-1} \sum_{i=0}^{\infty} \left( \beta \lambda_{1} \right)^i E_{t-2}^{1} \left[ p_{t+i+1} \right]
\]

\((12)\)

Output decisions in \((12)\) are clearly made on the basis of expected output and input prices and are also function of past output decisions due to the presence of adjustment costs.

The structure of how anticipations for the wholesale and farm prices are formed must now be specified. The wholesale price is an autoregressive process of order one with drift. As described in the introduction, the farm price is determined through a bilateral negotiation process, and thus the expectations about the outcome of this bargaining process must be modeled. At this stage,
producers can exercise their collective bargaining strength conferred by their monopoly status. The output allocation rule determines total revenues in the industry while the farm pricing system establishes how total revenues will be split between producers and processors. The bargaining model of Gervais and Devadoss (2006) is used to model the price bargaining equation. It assumes that the farm price at time $t$ is function of the expectation at time $t-1$ of the wholesale price and producers’ costs:

$$ r_t = \gamma_p E_{t-1}[p_t] + \gamma_w E_{t-1}[w_t] + z_t \tag{13} $$

where $z_t$ is a mean zero error term with variance $\sigma_z^2$. The parameters $\gamma_p$ and $\gamma_w$ capture the relative bargaining power of chicken producers and processors, respectively. For example, an increase (decrease) in $\gamma_w$ implies that the relative bargaining power of processors increases (decreases) as the farm price is set closer (further) to producers’ average costs. This approach is connected to the bilateral bargaining model of Rubinstein (1982) because it is based on average revenues and costs in the supply chain. The structure of expectations is consistent with the timing of the bargaining game outlined in Figure 4.

We assume adaptive expectations for average production costs and the wholesale price. As such, the variable $w_t$ follows an autoregressive process of order one with drift, as in the case of the wholesale price stated earlier. The price bargaining system using our usual time $t-2$ perspective can be written as:

$$ r_{t-1} = \gamma_0 + \gamma_p p_{t-2} + \gamma_w w_{t-2} + z_{t-2} $$

$$ p_{t-2} = \mu_p + \rho_p p_{t-3} + e_{p,t-2} $$

$$ w_{t-2} = \mu_w + \rho_w w_{t-3} + e_{w,t-2} \tag{14} $$

where $\mu_p$ and $\mu_w$ are deterministic drifts, $\gamma_0 \equiv \gamma_p \mu_p + \gamma_w \mu_w$ summarizes the combined drift terms in the stochastic processes of the wholesale and feed prices, $\rho_p$ and $\rho_w$ are first-order autoregressive coefficients and $e_{p,t-2}$ and $e_{w,t-2}$ are error terms with mean zero and potentially nonzero contemporaneous correlation with the farm price random shock at time $t-1$ given the timing of decisions in the model.

Substituting (14) into (12) yields:

---

7 This rationalizes the assumption introduced earlier of constant returns to scale in broiler production.

8 Another avenue would have been to specify a set of market clearing conditions to determine the wholesale price and thus use a procedure consistent with rational expectations.
\[ q_t = -\frac{\lambda_t}{d(1-\beta^t)} + \lambda_t q_{t-1} + \frac{\beta t}{b_t d} \sum_{i=0}^{\infty} \left( \beta^{i} \right) E_{t-2} \left[ p_{t+1+i} \right] \]

\[ -\frac{\lambda_t}{d(1-\beta^t)} + \lambda_t P_{t-1} \sum_{i=0}^{\infty} \left( \beta^{i} \right) E_{t-2} \left[ w_{t+1+i} \right] \]

As before, we use the properties of the stationary autoregressive processes to solve for the expectation terms and rewrite the output equation as:

\[ q_t^B = \frac{\beta t}{b_t d(1-\beta^t)} \left( 1 - \frac{1}{1-\beta^t} \right) \frac{\lambda_t}{d(1-\beta^t)} \]

\[ + \frac{\beta t}{b_t d(1-\beta^t)} \frac{\lambda_t}{d(1-\beta^t)} + \lambda_t q_{t-1} \]

\[ + \frac{\beta t}{b_t d(1-\beta^t)} \left[ \beta p_p - b_t \gamma_p \right] p_{t-2} - \frac{\lambda_t}{d(1-\beta^t)} w_{t-2} \]

where the superscript \( B \) denotes the bargaining pricing mechanism.

The main objective of the paper is to compare the two different pricing mechanisms in the Canadian chicken industry. The most significant difference between the bargaining and the “cost-plus” mechanisms is the determination of the farm price. Under the “cost-plus” system, the farm price is \( r_t = k w_{t-2} \), where \( k > 1 \) represents the producers’ margin. Using (12), we can write the output equation under “cost-plus” as:

\[ q_t = \lambda_t q_{t-1} - \frac{\lambda_t}{d} \sum_{i=0}^{\infty} \left( \beta^{i} \right) E_{t-2} \left[ w_{t-2+i} \right] + \frac{\beta t}{b_t d} \sum_{i=0}^{\infty} \left( \beta^{i} \right) E_{t-2} \left[ p_{t+1+i} \right] \]

As before, the properties of the autoregressive processes allow us to rewrite output as:

\[ q_t^{CP} = \frac{\beta t}{b_t d(1-\beta^t)} \left( 1 - \frac{1}{1-\beta^t} \right) \frac{\lambda_t}{d(1-\beta^t)} \]

\[ + \frac{\beta t}{b_t d(1-\beta^t)} \frac{\lambda_t}{d(1-\beta^t)} + \lambda_t q_{t-1} + \frac{\beta t}{b_t d(1-\beta^t)} p_{t-2} - \frac{\lambda_t}{d(1-\beta^t)} w_{t-2} \]

where the superscript \( CP \) denotes the “cost-plus” pricing mechanism. Equations (7), (15) and (16) can be used to compare the different solutions under the two pricing mechanisms. Given the hypothesis of risk neutrality, sales are identical under the two scenarios. Output levels however need not be. To gain a little insight, assume that the constant in the farm cost and wholesale price autoregressive processes are zero. The difference in output under the two pricing mechanisms is:
The production smoothing effect of adjustment costs in production (captured by the parameter $\lambda_1$) is identical across mechanisms. However, the overall level of output from one period to the next will depend on the bargaining strength of processors and producers as well as the margin coefficient $k$. An increase in $k$ will increase the likelihood that output under bargaining be larger than under “cost-plus”. Conversely, an increase in the relative bargaining power of producers through an increase in the parameter $\gamma_p$ will decrease the difference between output levels under the two regimes. The difference in output is also negatively correlated with adjustment cost parameter, $d$. An increase (decrease) in $d$ implies that output will be less (more) responsive to changing market conditions. Given the “bargaining” system is more correlated to output price movements, an increase (decrease) in $d$ is likely to yield a lower (greater) difference between output levels in (17). If the adjustment costs are very large (such that the parameter $d$ goes to infinity), the autoregressive coefficient in the output equation will tend to one, and thus output at time $t$ will simply be equal to output level at time $t-1$.

3. Data and Estimation

The theoretical model is applied to the chicken industry in Ontario. More than 33 percent of all chickens in Canada were produced in that province in 2005. Price and quantity data were provided by Chicken Farmers of Ontario (CFO). Live chicken prices for each quota period were converted on a eviscerated basis using a coefficient of 0.736. Weekly wholesale prices for different chicken meat cuts were used to compute a single weekly wholesale price for chicken meat. The weekly wholesale prices were averaged out over each quota period. Weekly data on chicken retail prices were also collected to construct a retail price for each quota period in a way similar to the wholesale sector. Finally, chicken producers’ costs include chick and feed costs. Chick costs vary very little over the sample period; hence the only significant source of producers’ cost uncertainty comes from feed prices. Weekly feed prices from two major feed mills in Ontario were used to compute an average feed price for each quota period. Figure 5 illustrates the retail, wholesale and farm prices in Ontario as well as the chicken production cost index for each quota period. We have a total of 49 quota periods.

There are five equations to estimate in the model: the sales equation in (7), the output decision rule in (15) and the pricing equations in (14). There are likely efficiency gains associated with estimating these equations simultaneously.
Because the coefficients $\gamma_p$ and $\gamma_w$ capture the relative bargaining power of each group, it makes sense to normalize the coefficients such that they sum to one ($\gamma_p + \gamma_w = 1$) when estimating the system of equations.

Figure 5. Retail, wholesale and farm chicken prices and farm average production costs for the A-1 to A-49 periods

The Generalized Method of Moments (GMM) is used to estimate the system of equations because of simultaneity issues. The GMM method sets 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 our case, the weighting matrix is obtained using the residuals generated by a Nonlinear Three Stage Least Squares (N3SLS) estimator with a Bartlett kernel. The truncation parameter of the bandwidth is selected according to the formula $l = 4(T/100)^{2/9}$, where $T$ denotes the number of observations. 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). In our case, we use a total of eight instruments which include lagged values of exogenous and endogenous variables.

http://www.bepress.com/jafio/vol8/iss1/art1
Fuhrer, Moore and Schuh (1995) warn that the GMM estimator for linear-quadratic inventory models may suffer from important small sample biases when compared to a maximum likelihood estimator. However, the biases they report seem to come from poor instruments, and because unreported experiments with a Full Information Maximum Likelihood (FIML) estimator produced poor results, we carried out the estimation using GMM.\(^9\) It is common in the linear-quadratic inventory literature (see for example West 1995) to normalize a coefficient associated with one of the cost convexities in (2) (either \(a\), \(c\), or \(d\)) because doubling all coefficients leaves unchanged the first-order condition apart from a rescaling of the residuals. The first-order condition in (9) does not suffer from such a problem. In the current approach, identification is achieved through the introduction of: i) a lag between the moment sales and output decisions are made (output at time \(t\) is chosen at time \(t - 2\) unlike sales decisions that are instantaneous); and ii) a linear component in the cost function of processors (live chicken procurement costs, \(r_tq_t\)).

To reduce the non-linearity of the model, the discount factor was set to \(\beta = 0.983\) using a ten percent annual discount rate. The set of parameters that need to be estimated is: \(\{a, b_0, b_1, c, d, \rho_p, \rho_{\mu_p}, \mu_p, \mu_{\mu_p}, \gamma_p\}\). First attempts at estimating the full system of equations yielded mixed results. The estimate of the unconditional inventory target \((b_0)\) was negative and not significant. Moreover, the estimate of the drift parameter \((\mu_p)\) in the autoregressive process of the wholesale price was not statistically different than zero. The system of equations was re-estimated using the restrictions \(b_0 = \mu_p = 0\).

Table 1 presents the GMM estimates of the linear-quadratic model. A pseudo-\(R^2\) measure, defined as the squared of the correlation coefficient between actual and predicted output, reveals that the model explains about 76 percent of the variations in output, but only 13 percent of the variations in sales. These results are not too unusual for highly non-linear models. The \(J\)-test for over-identifying restrictions does not reject the null hypothesis that the model is correctly specified. The test statistic (11.96) is below the critical value (with thirty-two degrees of freedom) at the 5 percent significance level.\(^{10}\)

\(^9\) Another option would have been to directly estimate the Euler equations of the model defined by (3) and (8) instead of the observable structure of the model. Fuhrer, Moore and Schuh (1995) suggest that the differences between the two strategies are likely to be insignificant.

\(^{10}\) The degrees of freedom equal 5 (number of equations) \(\times\) 8 (number of instruments) - 8 (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).
The estimate of \( \gamma_p \) is 0.443 and significantly different than zero. The null hypothesis of equal relative bargaining strengths is rejected with a \( p \)-value of 0.001 indicating that processors have slightly greater bargaining power than producers \( (\hat{\gamma}_w > \hat{\gamma}_p) \); a result consistent with the findings in Gervais and Devadoss (2006). The estimate of the conditional target inventory parameter (denoted \( \hat{b}_1 \)) is 0.588. The three convexities in the global cost function of processors are governed by the parameters \( a, c \) and \( d \). The estimate of \( a \) is 0.8E-05 and significantly different than zero at the 1 percent significance level. The estimate of the parameter for the adjustment cost function (denoted \( \hat{d} \)) is 0.0019 and significant at the 1 percent level. The estimate of the processing cost function parameter (denoted \( \hat{c} \)) is 0.3E-04 and also significant at the 1 percent level. The above estimates are consistent with the assumptions introduced in the theoretical model (in particular that \( \phi < 1 \)).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a )</td>
<td>0.893 E-05</td>
<td>0.642 E-06</td>
</tr>
<tr>
<td>( b_1 )</td>
<td>0.589</td>
<td>0.015</td>
</tr>
<tr>
<td>( c )</td>
<td>0.347 E-04</td>
<td>0.159 E-05</td>
</tr>
<tr>
<td>( d )</td>
<td>0.193 E-02</td>
<td>0.234 E-03</td>
</tr>
<tr>
<td>( \mu_w )</td>
<td>0.308</td>
<td>0.013</td>
</tr>
<tr>
<td>( \rho_w )</td>
<td>0.749</td>
<td>0.012</td>
</tr>
<tr>
<td>( \rho_p )</td>
<td>0.967</td>
<td>0.002</td>
</tr>
<tr>
<td>( \gamma_p )</td>
<td>0.443</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Note: All estimates are statistically different than zero at the 1 percent significance level.

### 4. Simulations

The structural parameters of the model can be used to simulate decisions under the “cost-plus” system. Output determination mechanisms are similar between the bargaining and “cost-plus” pricing systems, but price expectations differ, and thus optimal output decisions will ultimately be different. To make meaningful comparisons between the two marketing systems, we keep the time \( t-2 \) perspective. Under the “cost-plus” mechanism, the price of live chickens is known. This certainty with respect to the farm price has no direct bearing on the
processors’ output decision given the hypothesis of risk neutrality. However, the model can entertain the possibility that chicken producers are risk-averse. In this instance, a system that yields higher expected profits than another system may not be preferred to the latter because it may also affect the risk faced by producers at the output determination stage.

Using the structural parameters in Table 1 and the optimal output levels defined in (15) and (16), we computed the predicted output under the two different pricing systems. Figure 6 plots the predicted output levels for each allocation period, as well as the actual output under the bargaining pricing system. The predicted “cost-plus” and bargaining output levels follow very similar patterns; the only difference being that output under “cost-plus” is always lower than under bargaining. From equation (12), it is apparent that this difference stems from the difference in expected future procurement costs of processors, i.e. whether processors expect to commit to a price higher or lower than the expected farm price under the bargaining scenario. Figure 7 plots the discounted sum of expectations about the farm price under the two pricing systems for each quota period. The evidence clearly suggest that the “cost-plus” system yields expectations of a higher farm price under the parametric assumption that \( k = 1.39 \); which was the first margin set in May 2003 when the cost-plus system was implemented (Gervais, Guillemette and Romain, 2007).

![Figure 6. Actual and predicted output levels under the bargaining and “cost-plus” pricing systems](image-url)
A decrease (increase) in procurement costs increases (decreases) processors’ output in a static framework, but adjustment and inventory costs also introduce additional secondary effects. Lower output implies a lower planned inventory level at time $t$, all other things being equal, and this has an impact on the deviations from the optimal target level. The presence of adjustment costs in output also reduces the incentive to lower output due to the higher price under the “cost-plus” system. The prevalence of these secondary effects are captured by the first-order autoregressive coefficient ($\lambda_1$) in the output equation. Indeed, there exists a strong persistence in output given that the estimate of $\lambda_1$ is 0.88.

In order to compare the two scenarios from the producers’ perspective, we need to compute expected profits at time $t$ defined in equation (1) from a time $t - 2$ perspective: $E_{t-2} [\pi_t = r_t Q_t - w_t Q_t]$. At first glance, it is not obvious that producers will prefer one system over the other. The lower output under the “cost-plus” system would tend to lead producers to support the bargaining system. However, we argued before that this lower output was mainly due to a higher farm price, and thus selling at a higher price under “cost-plus” may benefit producers.
To investigate the implications of the two pricing systems on profits, we carried out a Monte Carlo simulation. In addition to a point estimate of expected profit in each quota period, this exercise allowed us to build a confidence interval around the point estimate. The procedure is quite simple. We use the estimated variance-covariance matrix of the residuals from the system in (7), (14) and (15) to draw a large number of correlated shocks (5,000 in this case). These shocks are used to generate an equivalent number of in-sample predictions of the endogenous variables. These predictions are used to simulate expected profits under the two pricing mechanism. The simulated expected profits of each quota period are sorted in ascending order, and the bottom and top 5 percent of simulations are used as the bounds of a 90 percent confidence interval.

Figure 8 plots expected profits of each period from a time $t - 2$ perspective under the two different pricing mechanisms. The dotted lines represent the 90 percent confidence interval of the producers’ expected profits. Average expected profits are $14,196$ thousand and $16,101$ thousand, respectively, under bargaining and “cost-plus”. The point estimate of expected profits under the cost-plus system is higher than under the bargaining system in 39 of the 45 quota periods. This difference is significant for 14 quota periods as the confidence interval of expected profits for “cost-plus” is located above the confidence interval of expected profits under bargaining. It should also be noted that the standard deviation of the point estimate of expected profits over the 45 quota periods is lower under “cost-plus” ($1,739$ thousand) than it is under the bargaining scenario ($2,496$ thousand).

Given the reduction in variability and the higher expected profit under “cost-plus”, it is not surprising that producers supported the reform in pricing mechanisms. Moving from a bargaining system to a formula-based price has not removed the importance of the relative bargaining strengths on the overall resulting split of benefits in the industry as noted in Gervais, Romain and Guillemette (2007). For example, a 5 percent reduction in the margin parameter $k$ (from 1.39 to 1.32) significantly reduces the point estimate of expected profits under “cost-plus” (to $12,957$). Hence, evolving bargaining strengths may have had an influence on the perceived advantages of one system over the other.
5. Concluding Remarks

This paper evaluates the efficiency of marketing institutions in the Canadian chicken industry using a linear-quadratic inventory model. Canadian chicken processors are assumed to be risk-neutral and face quadratic output adjustment costs and inventory costs that are quadratic in the difference between actual and target inventories. The theoretical model yields non-linear decision rules for output and sales that are function of lagged endogenous variables and price expectations. The price bargaining equations are estimated jointly with the sales and output decision rules. A GMM estimator accounts for simultaneity issues in the system of equations. The estimation procedure yields statistically significant parameters that are related to processing, adjustment and inventory costs.

A simulation exercise is carried out to investigate the rationale behind the Canadian chicken producers’ apparent support of the 2003 reforms in marketing institutions which involved moving from a price bargaining system to a pricing system based on their average production costs. The simulation reveals that producers’ expected profits are higher under the “cost-plus” pricing mechanism than under bargaining. Moreover, the cost-plus system is predicted to lower the variability of producers’ profits. Producers have been successful reversing the
decline in the chicken live price under the bargaining framework and the higher procurement costs for processors have not triggered a significant reduction in the industry output.

6. References


