The Farm-Wholesale Price Spread in an Imperfectly Competitive Market: A Dynamic Approach

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Abstract

The purpose of this paper is to discuss dynamic methods in the measurement of market power for a perishable commodity. A dynamic programming solution suggests an optimal behavior rule for a representative marketing firm. Besides profits from market power exploitation, the optimal rule considers the impact of current behavior on future market outcomes through the acreage response of farmers.

To generate an empirical application, a maximum likelihood procedure is outlined. An application of the model to the Peruvian potato market is also discussed.

The proposed model has certain advantages over static models of exogenous prices and models where no supply response is assumed. The structure of the optimal behavior model also constitutes an advantage with respect to non-structural time series models in terms of its potential for policy analysis.

This paper is part of a study in progress.

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1 Introduction

Market Power impacts and effects are areas of interest to commodity market analysts. Numerous studies have examined the degree of oligopsony (oligopoly) power in the input (output) market for specific marketing and processing industries. In assessing market power, economists have relied on assessment processes collectively labeled as New Empirical Industrial Organization (NEIO). In contrast to the Structure Conduct Performance Paradigm (SCPP) described by Bain (1950), NEIO studies utilize parameterizations of the industry conduct rather than accounting relationships (Bresnahan, 1988).

While some NEIO studies focus on measures of deviations from marginal cost pricing within a static framework (Schroeter, 1988; Holloway, 1991; Schroeter and Azzam, 1991; Rogers and Sexton, 1994; Love and Shumway, 1994), other studies emphasize dynamic relationships between input and output prices using time series analysis (for example Alavalapati et al. 1997 for the case of the Canadian Wood Pulp Industry). Although the dynamic nature of market power has been recognized (Geroski, 1988) structural dynamic studies are less common.

In this paper a structural dynamic approach of non-competitive behavior in the marketing system for a perishable product is proposed. In particular, implications derived from a dynamic supply response are considered. It is recognized that past acreage utilization affect current crop productivity. Under rational expectations farmers' supply response is the result of optimal dynamic land allocation plan (Eckstein, 1984; Tegene et al. 1988).

In an imperfectly competitive market dynamic supply response implies a trade-off in earnings for the marketing firm. Greater current gains from oligopsony power imply reduced future profits. In this paper trade-offs are examined as a dynamic programming context for a representative marketing firm. Bellman's principle provides an insightful behavior rule to examine firms' actions. Bellman's principle examines deviations from marginal cost pricing plus the value of the impact of current decisions on future profits.

For an empirical application of the model, functional forms of the value function and of the farm supply response are unknown, so a fixed-point/maximum likelihood algorithm is outlined to recover an objective function starting from observable statistical data and accounting for unobserved state variables. This is a continuous choice extension of the algorithm proposed by Rust (1988) for discrete choice models.

In what follows, the second section is a derivation of the dynamic model and its optimal conditions. The econometric estimation approach is described in the third section. The fourth section discusses the application of the model to the case of the Peruvian potato market. Finally, in the fifth section some implications of the dynamic model are outlined, and a direction for further research is proposed.

2 Dynamic Model

Current productivity of land decreases after each successive period that the same crop is planted, so there is interdependence between past acreage utilization and current productivity (Eckstein, 1984; Tegene et al. 1988). This interdependence defines optimal land allocation and crop rotation planned by farmers, since current output depends on current acreage and on the cropping history of the land. Expected farm prices are also a critical decision factor in acreage allocation. For example, if the expected price more than compensates the expected lower yields (and possible additional costs), a farmer may decide to allocate land to the same crop for multiple periods.

For each period, total harvest (H_t) can be expressed as a function of current and past land allocations (A_t, A_{t-1}), expected farm prices (w^e_{t+1}) and a set of exogenous variables (X_1) that includes potential revenues of alternative crops.

$$\begin{aligned} H_{t+1} &= \varphi(A_t, A_{t-1}, w^e_{t+1}, X_1); \\ w^e_{t+1} &= E[w_{t+1}|\Omega_t]. \end{aligned} \tag{1}$$

In a dynamic setting with exogenous prices, an optimal land allocation sequence $A_0, A_1, ..., A_T$ can be obtained by maximizing farmers' revenues. However, when imperfect competition and endogenous prices are considered, expression (1) has additional implications for price and quantity determination.

The particular case of a perishable commodity will be analyzed. It will be considered that there is a main market for this commodity where most of the production is traded. In addition, storage, processing and imports will not be considered as significant price stabilization mechanisms. Most production is traded in the main market, but some alternative destinations for the output, such as self consumption, minor markets and animal feed are possible. Therefore, available supply in the main market Q is a fraction of the total harvest.

In response to the dynamic nature of acreage decisions, the optimization problem for a representative marketing firm must include the effect of current market outcomes on future acreage. This involves a sequence of market actions that maximize the present value of current and expected profits (π) over time. The market action is a sequence of volumes q contingent to the state given by the availability of the commodity in the market (Q), which ultimately is determined by the size of the harvest (H).

The objective of the firm is

$$\max_{\{q_\tau\}_{\tau=t}^{T}} E \sum_{\tau=t}^{T} \rho^{\tau}\ \pi(H_\tau, q_\tau). \tag{2}$$

Profits for firm i at period t are given by

$$\begin{aligned} \pi(H_t, q_{it}) &= (p_t - w_t - c(q_{it}) \cdot q_{it} \\ &= [D^{-1}(Q_t) - S^{-1}(Q_t) - c(q_{it})] \cdot q_{it}, \end{aligned} \tag{3}$$

where p_t and w_t are the retail and farm prices respectively, that can also be expressed as the inverse demand (D^{-1}) and supply (S^{-1}) functions; $c(q_{it})$ is a per unit marketing cost.

The problem expressed in (2) can be analyzed using dynamic programming principles. The basis of dynamic programming is that the multiple period maximization problem (2) is reduced to a sequence of two period problems, in which the optimizing agent faces the need to balance an immediate reward with expected future rewards. The solution to this intertemporal optimization is given recursively by Bellman's equation:

$$V_{it}(H_t) = \max_{q_i} \{\pi(H_t, q_{it}) + \rho E[V_{it+1}(H_{t+1})]\}. \tag{4}$$

The interpretation of (4) is that in each period, the agent (firm i) attempts to maximize the value of current and expected future rewards. If an infinite horizon is considered, then the value functions are the same for every period so the value function satisfies

$$V_i(H) = \max_{q_i}\ \pi(H, q_i) + \rho E[V_i(H^{'})] \tag{5}$$

where H and $H^{'}$ are a current and a future states respectively.

The solution to (5) can be characterized by first order conditions, or Euler conditions. The first order condition implies that the optimal action q_i, given the state H and the transition $H^{'} = \varphi(\cdot)$ satisfy

$$\pi_q(H, q) + \rho E[V_i^{'}(\varphi(\cdot)) \cdot \varphi_q(\cdot)] = 0 \tag{6}$$

where π_q and φ_q denote partial derivatives.

If there are N marketing firms, then $Q_t \equiv \sum_i^N q_{it}$. If firm i has market power, the collective response to a change in its choice is given by dQ/dq_i, which links Q to q. If each firm chooses its output independently of its rivals (Nash equilibrium in quantities), the N choices of q_i simultaneously satisfy the optimal solution to the dynamic problem.

A distinction between oligopoly power and oligopsony power is required. This distinction will be made in the measure of the collective response to the firms' actions. When the firm has oligopsony power the collective response occurs on the farm side ($dQ^s/dq_i \equiv \theta_i$), and oligopoly power occurs in the consumer market side ($dQ^d/dq_i \equiv \lambda_i$). Applying this distinction, an explicit form for (6) using (3) under market equilibrium is:

$$p_t\left(1 + \frac{\lambda_i}{\eta}\right) - w_t\left(1 + \frac{\theta_i}{\varepsilon}\right) + \rho E[V_i^{'}(\varphi(\cdot)\ \varphi_q(\cdot)] = 0. \tag{7}$$

equation (7) reflects total effects from market power. The first two terms are usual deviations from competitive pricing as measured by conjectural elasticities divided respectively by the demand (η) and supply (ε) elasticities (Schroeter and Azzam, 1988). The third term reflects the marginal value that firm i assigns to the impact of its actions on future market results. If the firm does not have oligopsony power, θ_i is zero and the value assigned to future market outcomes disappears.

An practical question concerns to how to use expression (7) to measure the degree of non-competitive conduct in a commodity market. Two important issues must be addressed. First what are the necessary assumptions needed to aggregate equation (7) and thus generate a valid expression for market power. Secondly what are the appropriate econometric procedures needed to estimate parameter values.

The aggregation issue depends on the non-competitive behavior model adopted to reflect the workings of the market under study. To focus on the estimation procedures, attention will be restricted to symmetric equilibria in which every firm trades (purchasing on farm, and selling in the main market) the same volume of the commodity. This assumption is appropriate when all firms possess identical technologies, which is likely to be the case in raw commodity markets where the main marketing function is transportation.

Symmetric equilibria implies that the values in expression (7) are the same for all firms. In particular, $V_i(\cdot) = V_j(\cdot)$, $\theta_i = \theta_j$ and $\lambda_i = \lambda_j$;$\forall i \neq j$. Therefore by suppressing the firm's subscripts an expression for aggregate market behavior is obtained. Econometric estimation of this expression will be discussed in the next section.

3 Econometric Procedures

Statistical inference with the model described in the previous section implies testing simultaneously two hypotheses. The first is that the behavior of the marketing system is driven by dynamic considerations. The second hypothesis is that there is a deviation from marginal cost pricing in the marketing sector, that is, market power. Under the hypothesis that (7) reflects the true market process, observed time series data of harvest, prices and volumes of trade can be interpreted as realizations of the dynamic model.

Estimation difficulties arise because functional forms for the value function V and the transition $\varphi(\cdot)$ are unknown. In addition, the observed state is only a subset of the variables observed by the marketing firm.

The statistical problem then, consists in inferring the underlying mathematical objective function by using observed time series data. By doing this, the goal is not limited to the determination of the stochastic processes that govern the evolution of observed variables. Imposing more structure to the problem increases the potential for the model to be used in policy analysis.

The literature on estimation of dynamic choice processes tends to focus on discrete choice problems (cf. Rust, 1994). However, since in the marketing system problem variables such as quantities and prices may take virtually any non-negative value, a continuous choice space method is required. In a seminal paper, Hansen and Singleton (1982) developed a procedure for the class of continuous control processes with rational expectations (Generalized Method of Moments or *GMM*) based on the transversality conditions implied by the stochastic Euler equations. However, *GMM* requires all the state variables to be observed by the analyst. A method to interface continuous control processes and statistical estimation theory is required.

A maximum likelihood procedure, similar to that of Rust (1988) can be developed for the continuous choice case. The procedure starts by defining a parameter vector β that includes the parameters of the value function, and of the reward function. Since only a subset of the state variables is observed, the decision rule follows the statistical model $q_i = g(H_t, \epsilon_t, \beta)$ where ϵ_t is a vector of state variables observable to the marketing firm but not to the analyst. Then Bellman's equation can be expressed as

$$V_\beta(H, \epsilon) = \max_q \Big(\pi(H, q, \beta) + \rho E[V_\beta(H^{'}, \epsilon^{'}] + \epsilon(q)\Big). \tag{8}$$

The form of the objective function is uncovered by finding the parameter vector

$\hat{\beta}$ that maximizes the likelihood function for the observed sample of data.

Some transformations to the state space are required in order to generate consistent estimates. These transformations amount to assume that the reward function is separable into an observed component with an unobserved parameter vector $(\psi(H, \epsilon, q, \beta))$ and an unobserved component $(\omega(\epsilon, q))$. Let $\xi \equiv \omega(\epsilon, q)$; then $\{H_t, \xi_t, q_t\}$ follow a controlled *Markov* process with probability density

$$\phi(H_{t+1}, \xi_{t+1}|q_t, H_t, \xi_t, \beta). \tag{9}$$

The next step is to assume that H_t, ξ_t have Conditional Independent distributions, so the Markov density function can be factored as

$$\phi((H_{t+1}, \xi_{t+1}|q_t, H_t, \xi_t, \beta) = \phi_1(H_{t+1}|H_t, q_t, \beta) \cdot \phi_2(\xi_t|H_t, \beta) \tag{10}$$

where ϕ_1 and ϕ_2 denote generic density functions (Rust, 1988).

Expression (10) implies that the likelihood function for the sample is given by the function

$$L(\beta) \equiv L(H_1, ..., H_T, q_1, ..., q_t|\beta) = \prod_{\tau=2}^{T} P(q_t|H_t, \beta) \cdot \phi_1(H_t|H_{t-1}, \beta) \tag{11}$$

where $P(q_t|H_t, \beta)$ is the conditional probability of q_t that includes the expected value function $E[V_\beta] \equiv EV_\beta$ among its terms. Rust shows that EV_β is the unique solution to a contraction mapping given by

$$EV_\beta = E_H[exp\{\pi(H', q', \beta) + \rho EV_\beta(H', q')] \tag{12}$$

with E_H denoting the expectation over ϕ_2. Rust also shows that consistent estimates of β can be obtained by maximizing the constrained "partial likelihood" function

$$L_p(\beta) \equiv \prod_{t=1}^{T} P(q_t|H_t, \beta) \tag{13}$$

where the restriction is given by (12). This procedure can be performed within conventional time series analysis. The required algorithm should solve the fixed point problem in each iteration.

The next step of this study (in progress) will involve defining the required parameterizations to develop the empirical application to the case of the Peruvian potato market.

4 The Peruvian Potato Market

Wholesale and farm potato prices in Peru were highly volatile in the last decades. Data for the period 1980-97 shows a decreasing trend of deflated prices, accompanied by large fluctuations around a trend line. While this behavior was unstable, the joint movement of farm and wholesale prices reveals imperfect transmission of fluctuations, with a high volatility of the farm-wholesale price ratio around a constant mean.

While there has been high degree of consensus that the potato marketing system is non-competitive, and that marketing agents' profits are excessive, research on this area is limited. Moreover, well documented studies (Scott, 1985) have found evidence that questions most of the generally accepted conceptions about concentration and excessive marketing margins.

The evidence of the farm-wholesale price ratio of potatoes tends to support the view that there is non-competitive conduct occurring in the Peruvian potato market. However, detailed knowledge about impacts from market power as measured by its effects on prices, farm income, production and food availability requires deeper analysis concerning the structure of the market and the interaction among farm production and market variables.

Relative farm prices decreased over the past two decades. Per capita consumption has also had a sharp declining trend (around 70% according to FAO). While the direction of these effects is consistent with increasing market power, some effects in the opposite direction, like a decreasing trend on the relative wholesale price, a non-increasing trend of the farm-retail price ratio, and an increasing trend of potato production, have to be considered in the analysis.

With time series data concerning prices, acreage and production, shipments to the main market (Lima) and marketing cost variables (e.g., fuel), it is possible to apply the dynamic model proposed in this study, to a specific case. The goal is not only to provide measures of non-competitive conduct and of its evolution across time, but also to generate a structural model for policy analysis. For its simple structure, the potato market is a good case to test the hypothesis of a marketing system behaving according to the model of dynamic optimization.

5 Concluding Remarks

In this paper, dynamic programming has been proposed as a framework for the analysis of non-competitive behavior in the market for a raw commodity. The dynamic link is given by a supply response mechanism based on crop rotation and farmers' price expectations.

In this context, optimization of the theoretical model using Bellman's principle, explains deviations from marginal cost pricing not only in terms of conjectural elasticities, but also in terms of the value that the firm assigns to the effects of its own actions on the future availability. Some of the advantages of this approach are that the measures of market power are endogenously determined, and that intertemporal effect of market results over farmers decisions is recognized. The model also has certain advantages over reduced-form statistical methods in terms of facilitating the analysis of the effects of policy changes.

Empirical estimation, has its complications since statistical methods for the estimation of continuous control processes are restricted to the case where all the state variables are observable. An extension of maximum likelihood estimation techniques to discrete control processes is described in this paper. Additional work is needed to generate the estimation algorithms and to determine the properties of the resulting parameter estimates.

As an application, the Peruvian potato market is proposed, because of the consensus about the non-competitive behavior of the marketing system. Available evidence seems to support the view that there is some degree of market power in the marketing system. This can be seen trough a decreasing trend of prices in recent years, a declining per-capita consumption, and an imperfect transmission of farm and wholesale price fluctuations.

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