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STATE TRADING ENTERPRISES IN A DIFFERENTIATED PRODUCT ENVIRONMENT:

THE CASE OF GLOBAL MALTING BARLEY MARKETS

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The lack of transparency in the pricing and operational activities of state trading enterprises (STEs) has caused WTO members to express concern that certain countries' STEs might circumvent Uruguay Round commitments on export subsidies, domestic support, or market access. The purpose of this study is to examine the market structure of the differentiated world malting barley market in which two STEs (the Canadian Wheat Board and Australian Barley Board) maintain jointly a very large share of the export market. In particular, this study focuses on the exclusive procuring and pricing policies used by both STEs to test if these intra-country mechanisms can generate leadership and shift rent from other exporting countries. A conceptual and empirical framework is also provided to test if STEs set their initial payments at optimal levels. Four key results are forthcoming from this research. First, we found strong support that the global malting barley market operates in a quantity setting oligopolistic structure. Second, both STEs and other exporting countries were in Cournot competition, and thus held the potential to exercise rent-shifting behavior using their initial payment structures. Third, while some distortionary impacts from the STE prepayment systems were possible, we did not find evidence that it was a tool either STE employed. Empirical results from the precommitment stage show that both STEs did not set their initial payments low enough to maximize their profits. Fourth, It appears that the strong anecdotal and statistical evidence of product differentiation dampened significantly the desire/ability of malting barley STEs to pursue a rent-shifting objective.

Keywords: State Trading Enterprises, product differentiation, malting barley, delayed payment system, rent shifting, market structure.

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STATE TRADING ENTERPRISES IN A DIFFERENTIATED PRODUCT ENVIRONMENT: THE CASE OF GLOBAL MALTING BARLEY MARKETS*

by
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As early as 1947, the General Agreement on Tariffs and Trade (GATT) acknowledged state trading enterprises (STEs) as legitimate participants in international trade. The World Trade Organization (WTO) defines STEs as "government and nongovernmental enterprises, including marketing boards, which have been granted exclusive or special rights or privileges, including statutory or constitutional powers, in the exercise of which they influence through purchases or sales the level or direction of imports or exports" (see USDA 1997). Because STEs may be privately owned, the defining consideration is thus not governance but exclusive privileges. State trading is more prevalent in agriculture than in other economic sectors. In 1995 and 1996, 32 countries notified the WTO of 96 agricultural enterprises or organizations operating as STEs. While STEs operate over a broad range of agricultural commodities, they are most active in grains and dairy products (USDA 1998).

Given the exclusive or special rights of STEs, the potential to exert considerable influence on the world markets is certainly possible. Controversial issues such as price-pooling strategies, and single-desk marketing functions of several large agricultural based STEs [the Canadian Wheat Board (CWB); the Australian Wheat Board (AWB), and the Australian Barley Board (ABB)] have been a major concern in the U.S. over the past decade (GAO, 1995). In particular, questions have arisen as to whether the programs instituted by STEs could be tailored to circumvent the growing international commitments toward freer trade. Certainly, these are valid concerns: nations for centuries have tried to protect and promote politically powerful industries. Indeed, the reported objectives for operating STEs include protecting domestic markets from world market influence, maintaining a stable and adequate supply of key commodities for national defense purposes, and expanding and protecting export market shares (GAO, 1995). Moreover, STEs oftentimes purposely operate under a shroud of government bureaucracy, which makes discerning their internal activities difficult. Particularly, critics of state trading argue that lack of transparency in the pricing and operational activities of STEs could be used to mask export subsidies and import tariffs (USDA 1998). For example, U.S. producers have complained that the CWB subsidizes grain through its pricing policies to their competitive disadvantage (Dixit and Josling).

Much literature exists that examine STE trade impacts. McCalla and then Alaouze, Watson, and Sturges evaluated the international wheat market in terms of its oligopolistic characteristics and keenly identified the role of STEs. While Carter found no evidence of imperfect competition in the international barley markets, Schmitz and Gray found that the CWB captured annually $72 million in noncompetitive rents. Kraft, Furtan, and Tyrchniewicz (study funded by the CWB) found that the CWB generated $19/ton-$34/ton in benefits to farmers due to its single selling authority system. Carter, Lyons, and Berwald (study funded by Alberta Dept. of Agriculture) found virtually the opposite result: that is, bureaucratic inefficiencies within the CWB generate $20/ton-$37/ton in losses to Canadian farmers. Finally, general support for some form of STE leadership emerged from a variety of studies employing time series analysis of international grain prices (Goodwin and Smith; Smith, Goodwin, and Holt; Spriggs, Kaylen, and Bessler; and Goodwin and Schroeder). However, the bulk of past work had focused on price discrimination and price pooling (Carter; Schmitz and Gray; Alston and Gray; Brooks and Schmitz), single desk selling (Clark; Dixit and Josling; Gray, Ulrich, and Schmitz; Brooks; Carter and Smith), and marketing policy and practice (Wilson and Johnson; Carter, Loyns, and Berwald). Strategic behavior, delayed payment systems and other strategic factors were generally ignore.

The U.S. General Accounting Office (GAO) conducted two investigative studies covering a wide range of STE behavioral, organizational, and strategic issues (GAO, 1995, 1996). Although STEs were found generally in compliance of WTO rules, some activities were considered potentially inconsistent with WTO law, such as export licenses, tax advantages, transportation subsidies, and delayed producer payments. The GAO study (1996) viewed the delayed payment system as a potential source of concern but primarily focused on its added flexibility in controlling internal budgets. Hamilton and Stiegert (2000) drew attention to the vertical separation structure of the delayed producer payment system which links upstream producers and downstream STEs. Typically, as single-desk sellers, the STEs pay upstream producers a below-market initial payment upon the delivery of crops, and then provide a final payment after proceeds are generated in the downstream international markets. As a result, through setting low procurement prices, the delayed payment approach is capable of creating a credible marginal cost advantage for the STEs in the international market and generating essentially the same effect as an export subsidy. In the case of STEs, Hamilton and Stiegert (2000) established the formal equivalence between the delayed producer payment system and these more familiar forms of precommitment. Hamilton and Stiegert (2002) empirically evaluated the rent shifting hypothesis for a single STE operating in the international durum market. They found statistical support for hypothesis that the CWB acted as a Stackelberg leader and derived its leadership role from its delayed payment system.

From the advancing body of strategic trade theory, Brander and Spencer's rent-shifting strategic trade model has generated some of the greatest interest. In this model, one home firm and one foreign firm produce homogeneous products and compete in a third-country market. A key point from the seminal article by Brander and Spencer was that rent-shifting is only possible when markets are imperfect and there exists some form of precommitment from the government. Brander and Spencer demonstrated that this precommitment can occur when governments set a credible export subsidy in advance of the quantity decision by firms[i]. However, the concept of Stackelberg leadership is most sensible in a situation when only *one* firm can precommit. If both governments could offer export subsidies, it is possible that both countries may be worse off as the result of a subsidy war and the rent-shifting outcome collapses to a classic prisoner's dilemma (see Krugman). With two governments capable of precommitment, any rent shifted from other exporters would have to be shared, thus diminishing its incentive for use. The optimal strategic trade policy depends critically on details of the market (Eaton and Grossman). Product differentiation creates other opportunities for market strategies that are not available when products are close substitutes (i.e. price discrimination, brand identity etc). The point here is that STEs have at their disposal a potential form of a precommitment mechanism. Exactly how that mechanism functions in a product differentiated market is an interesting and important question to address.

The purpose of the research in this study is to evaluate the delayed producer payment system used by STEs in a differentiated market, the international malting barley market. Malting barley markets have historically operated with two STEs (the CWB and ABB) both of which maintain a similar initial payment structure. Malting barley maintains a sensitive product quality structure and much of what is planted for malting markets ends up as lower priced feed barley. There exists a convincing and growing literature that suggests a more differentiated market exists for most of internationally traded grains that go beyond the standard grading system (e.g., Stiegert and Blanc; Johnson, Grennes, and Thursby; and Marsh). In most cases, raw food commodities are differentiated by physical growing constraints, geographic origin, credit policies, delivery dates, and ancillary services. Therefore, unlike Hamilton and Stiegert's (2002) durum study, which confronted only one STE, and operated under the within the grading system and assumed product homogeneity across export nations, we develop a theoretical and empirical approach to evaluate rent shifting for a market structure with two STEs selling potentially differentiated products.

The organization of the remaining sections is as follows. First, we provide some information on STEs in the international malting barley market. Then we develop both theoretical and empirical models, and discuss data issues. Finally, we discuss the empirical results and summarize our findings.

STEs in World Malting Barley Markets

The CWB and the ABB are the two major STEs operating in the international export market for malting barley. The CWB is a single-desk state trading agency responsible for marketing all wheat and barley sold for human domestic consumption and for export, with jurisdiction over areas that typically produce 95 percent of the Canadian barley crop. One of the major responsibilities of the CWB is to market wheat and barley in order to maximize returns to prairie producers. At the beginning of each crop year, the government establishes initial producer payments for grain sold to the CWB. The initial payment is usually set low enough to avoid a deficit in the pool. Farmers get the initial payment upon delivery of the harvested crop. This acts as a price floor because the government will fund the pool should average market prices fall below the initial payment. Given the exclusive right, the CWB can obtain crops at low initial payments and thus have a marginal cost advantage in the world markets over other non-STE competitors who have to procure raw crops at higher market prices. Implicitly, the low initial payment works as an export subsidy for STEs in downstream markets. Once the CWB has marketed all the grain in a particular pool, the revenue is pooled, and freight and handling charges are deducted. If returns to the pool exceed the sum of initial payments, then a final payment is distributed to each individual producer based on the relative producer share of grain in that particular pool. The practice of pooling makes the final price paid to producers a blended price based on net revenue of all sales in foreign and domestic markets. The STEs pay producers the same return regardless of the time of delivery during the marketing year[ii].

The ABB had the sole right to export barley grown in South Australia and Victoria, which produce over half of all barley grown in Australia. The ABB accounted for about 90 percent of malting barley exports from Australia in 1992/93 [Center for International Economics (CIE)]. The domestic market for malting barley is effectively controlled through the single-desk power of the ABB. One of the objectives of the ABB is to maximize the net returns to growers who deliver barley or other grain to a pool of the Board. The ABB's prepayment system and operations are similar to those of the CWB. In 1999, the ABB was privatized and changed to ABB Grain Ltd. Its exclusive rights for domestic malting barley were eliminated in July 1999 and its single desk export rights for barley from South Australia and Victoria were eliminated in July 2001. It is worth noting that exporting STEs are neither middleman who attempt to exploit both producers and consumers nor monopsonists who exploit producers. Instead, STEs are producer monopolists, which return all profits earned from sales directly to producers (Schmitz et al).

For marketing purposes, barley is classified into feed and malting varieties. Malting barley is simply high-quality barley that has the appropriate characteristics to produce good malt. The malting barley is further divided into two-row and six-row varieties, for which brewer demands differ. Breeding programs, agronomic practices, soil characteristics, climatic conditions, and expected price differentials determine the varieties of barley grown in different regions. Farmers in Canada grow both 2-row and 6-row varieties of barley. Since 1991, plantings of 6-row white varieties have increased because of the contracts for the U.S. market. Australian barley producers almost exclusively plant 2-row varieties.

Conceptual Framework

This section describes the derivation of a theoretical framework to examine firms' behavior in a differentiated product market.

Theoretical Model

As discussed above, the delayed payment approach has the potential of creating a credible marginal cost advantage because STEs pay less to acquire exportable products and this has the same effect on marginal cost as an export subsidy. Moreover, in the case of STEs, the final payment in a delayed producer payment system, which is typically delivered in a lump-sum fashion, provides an explicit method of transfer back all profits to the input supplier that rationalizes the system. Therefore, the delayed producer payment structure is equivalent in this regard to a policy of direct export subsidization.

The analysis in this study was conducted on global malting barley markets. The malting barley market is considered to consist of potentially imperfect substitutes. Agronomic practices, soil characteristics, and climatic conditions determine barley varieties grown in different regions, and downstream brewers have specific quality requirements in terms of acceptable varieties, protein, plumpness and germination (Wilson and Johnson). Trade practices such as credit terms, delivery dates, and ancillary services add to the overall product differentiation. Finally, consumer preferences vary by region, personal taste, and suppliers and lead to a derived demand for various sets of malt characteristics.

We begin with a theoretical model that proposes endogenous control of an upstream supply in that STEs choose the initial prices of their principal raw commodity and then quantity compete in an international market of imperfect substitutes. We presume throughout that STEs and producers are vertically aligned and that the government grants the STE exclusive purchase rights of the raw commodity. The vertical structure analyzed here consists of two stages solved by backward induction. The first stage is an output stage, in which the STEs and other exporting firms maximize profits by choosing quantities. We estimate the output stage by considering STE trade policy as a given shift parameter in the domestic marginal cost function. In the preceding stage (precommitment stage), both STEs simultaneously choose their initial payments for the material input. In this stage, we employ a subset of the output-stage results to characterize the value of the trade policy parameter associated with the optimal degree of rent-shifting, which is consistent with the assumption that the government sets a subsidy level with the understanding of how it influences the output equilibrium.

Let x_1, x_2, and x_3 represent total sales of malting barley to the world market by the CWB (1), ABB (2), and the other malting barley-exporting countries (3), respectively, and denote the downstream inverse demand functions of malting barley marketed by the CWB, the ABB, and other exporting countries as P_1, P_2, and P_3, respectively. The country-specific inverse demand functions of malting barley which we assume continuous in all quantities and downward sloping in own quantity are as follows:

$$P_1 = P_1(x_1, x_2, x_3; \Phi_1) \qquad (1)$$

$$P_2 = P_2(x_1, x_2, x_3; \Phi_2) \qquad (2)$$

$$P_3 = P_3(x_1, x_2, x_3; \Phi_3) \qquad (3)$$

where Φ_is are exogenous variables. The form of inverse demand functions is general in terms of including both homogeneous and differentiated cases. If barley varieties were perfect substitutes or homogeneous, all the prices would be equal net of transport costs and each demand change generates a same effect on each price. Obviously, if barley varieties were imperfect substitutes, each demand change generates a different impact on each price.

In the output stage, the STEs and the firms in other exporting countries choose their outputs to maximize profits by

$$\underset{x_1}{Max}\ \pi_1(x_1) = P_1 x_1 - w_1 x_1 \qquad (4)$$

$$\underset{x_2}{Max}\ \pi_2(x_2) = P_2 x_2 - w_2 x_2 \qquad (5)$$

$$\underset{q}{Max}\ \pi_3(q) = P_3 q - c_3 q \qquad (6)$$

where w_1 and w_2 are initial payments set in the precommitment stage by the CWB and the ABB, respectively; and c_3 is the price received by farmers of other exporting countries. Here, we assume that there are n symmetric firms in the other exporting countries and thus $q=(1/n)x_3$. Without loss of generality, the profit function π_i is assumed to be continuous in all x and quasi-concave in x_i. The quasi-concavity of profit function, as demonstrated by Rosen, guarantees the existence of Nash equilibrium.

Maximization of equations (4), (5), and (6) with respect to x_1, x_2, and q, respectively yields the first order conditions:

$$P_1 + x_1(P_{11} + \gamma_{12}P_{12} + \gamma_{13}P_{13}) - w_1 = 0 \qquad (7)$$

$$P_2 + x_2(\gamma_{21}P_{21} + P_{22} + \gamma_{23}P_{23}) - w_2 = 0 \qquad (8)$$

$$P_3 + x_3(\gamma_{31}P_{31} + \gamma_{32}P_{32} + P_{33}) - c_3 = 0 \qquad (9)$$

where $P_{ij}=\partial P_i/\partial x_j \leq 0$ and $\gamma_{ij} = \partial x_j/\partial x_i$. The γ_{ij} (i, j=1, 2, 3, and i≠j) is the slope of the reaction function, indicating firm j's reaction or best response to the change of firm i's quantity. For example, γ_{12} indicates the ABB's reaction/best response to the output change of the CWB. The reactions of firms to other firms' output changes provide an index of the degree of market power, leading directly to the relevant first-order conditions for the various models. In particular, the price-taking, the collusive, and Nash-Cournot models are obtained as special cases of this general model. We treat this index of best response as a single parameter (Deodhar and Sheldon; Bresnahan), but, more generally, it might be a function of exogenous variables as in Gallop and Roberts.

When products are imperfect substitutes, the conditions for various market models are different from those under a homogeneous product scenario. In particular, each of the best response parameters (the $\gamma_{ij}s$) is weighted by the unique cross-price impacts (P_{ij}s) that can limit or exasperate the degree of market power. For example, for the CWB, if the term in the parentheses in equation (7) is equal to zero (i.e. if $P_{11}+\gamma_{12}P_{12}+\gamma_{13}P_{13}=0$), then the CWB is a price taker. However, when market power is present and as products become more differentiated, cross price effects dissipate and the own price effect takes on more relative weight. For the homogeneous case with market power, each of the best response parameters are equally weighted by the aggregate price effect ($\partial P_i/\partial x_j$), which can be easily reinterpreted as a market demand elasticity.

In equations (7), (8), and (9), the value of the γ_{ij}'s combined with the cross price effects gives an illustration of the market structure and the degree of competition. Specifically, the departure of the γ_{ij}'s from zero is a logically consistent test of whether the Cournot-Nash model provides an accurate description of the industry equilibrium.

Let $x_i(w_1, w_2; \psi_i)$ which is defined by the first order conditions in (7), (8), and (9) represent the equilibrium levels of sales from country i in the output stage, given initial payments of w_1 and w_2. The variable, ψ_i, are exogenous variables affecting supplies. To simplify the problem, we assume all other affecting factors of supply exogenous. In the precommitment stage, the STEs select transfer prices, w_1 and w_2, so as to

$$\underset{w_1}{Max}\ \pi_{1p} = P_1(x_1(w_1,w_2;\psi_1),x_2(w_1,w_2;\psi_2),x_3(w_1,w_2;\psi_3))x_1(w_1,w_2;\psi_1) - c_c x_1(w_1,w_2;\psi_1) - F_1 \tag{10}$$

$$\underset{w_2}{Max}\ \pi_{2p} = P_2(x_1(w_1,w_2;\psi_1),x_2(w_1,w_2;\psi_2),x_3(w_1,w_2;\psi_3))x_2(w_1,w_2;\psi_2) - c_a x_2(w_1,w_2;\psi_2) - F_2 \tag{11}$$

where π_{1p} and π_{2p} are the profit of producers under the CWB and the ABB, respectively. The variables c_c and c_a are the marginal production costs for producers in Canada and Australia, respectively. For simplification of the problem, production costs are assumed to be constant. The ψ_i are exogenous variables affecting supplies. Variables F_1 and F_2 are fixed costs that could include, respectively, marketing and administration costs incurred by the CWB and the ABB.

The first order conditions of equations (10) and (11) are

$$P_1\frac{\partial x_1}{\partial w_1} + x_1(\frac{\partial P_1}{\partial x_1}\frac{\partial x_1}{\partial w_1} + \frac{\partial P_1}{\partial x_2}\frac{\partial x_2}{\partial w_1} + \frac{\partial P_1}{\partial x_3}\frac{\partial x_3}{\partial w_1}) - c_c\frac{\partial x_1}{\partial w_1} = 0 \tag{12}$$

$$P_2\frac{\partial x_2}{\partial w_2} + x_2(\frac{\partial P_2}{\partial x_1}\frac{\partial x_1}{\partial w_2} + \frac{\partial P_2}{\partial x_2}\frac{\partial x_2}{\partial w_2} + \frac{\partial P_2}{\partial x_3}\frac{\partial x_3}{\partial w_2}) - c_a\frac{\partial x_2}{\partial w_2} = 0 \tag{13}$$

Using backward induction from (7) and (8) and substituting $P_i+x_iP_{ii} = w_i-x_i(\gamma_{ij}P_{ij}+\gamma_{ik}P_{ik})$ (i,j=1,2, i≠ j; k=3) into (12) and (13), the optimal upstream prices (let w_i*'s denote the optimal initial payments) set by the STEs are:

$$w_1^* - c_c = -x_1[P_{12}(\frac{\frac{\partial x_2}{\partial w_1}}{\frac{\partial x_1}{\partial w_1}} - \gamma_{12}) + P_{13}(\frac{\frac{\partial x_3}{\partial w_1}}{\frac{\partial x_1}{\partial w_1}} - \gamma_{13})] \tag{14}$$

$$w_2^* - c_a = -x_2[P_{21}(\frac{\frac{\partial x_1}{\partial w_2}}{\frac{\partial x_2}{\partial w_2}} - \gamma_{21}) + P_{23}(\frac{\frac{\partial x_3}{\partial w_2}}{\frac{\partial x_2}{\partial w_2}} - \gamma_{23})] \tag{15}$$

The comparative static effects $\partial x_i/\partial w_j$ (i=1, 2, or 3; and j=1 or 2) may be derived by taking total differential of equations (7), (8), and (9) and applying Cramer's rule (see Appendix 1 for expression).

In light of the attention devoted to strategic trade policy, the test of rent-shifting effects is certainly of great interest. "Rent-shifting" is a theoretical concept implying that governments can employ trade policy as a pre-commitment device to transfer profits from foreign to domestic markets. The hypothesis that the CWB and the ABB strategically utilized their pre-payment systems and product differentiation to shift rents from other foreign firms is seen from the following set of partial derivatives:

$$\frac{\partial \pi_i}{\partial w_j} = \sum_{\substack{k=1 \\ i \neq k}}^{3} \frac{\partial \pi_i}{\partial x_k} \frac{\partial x_k}{\partial w_j} \qquad (16)$$

The expressions $\partial x_k/\partial w_j$ was defined earlier and $\partial \pi_i/\partial x_k$ can be derived from equations (4), (5), and (6). If $\partial \pi_1/\partial w_1 < 0$ and $\partial \pi_i/\partial w_1 > 0$ (i= 2, or 3), the CWB can increase its profit at the expense of other exporters by lowering its initial payments. Similar analysis could be applied to the ABB. Unlike in the homogeneous product market, rent shifting in the product differentiated market not only depends on the market structure but also on cross-price effects, which indicate the degree of product differentiation.

Empirical Methods

A functional specification must be chosen to evaluate the hypotheses generated from the conceptual framework. To evaluate the degree of market power, it is necessary to identify γ_{ij}'s. Equations (7), (8), and (9) are expanded and rearranged to yield:

$$P_{1t} - w_{1t} = \lambda_{12}(P_{12}x_{1t}) + \lambda_{13}(P_{13}x_{1t}) - P_{11}x_{1t} \tag{17}$$

$$P_{2t} - w_{2t} = \lambda_{21}(P_{21}x_{2t}) + \lambda_{23}(P_{23}x_{2t}) - P_{22}x_{2t} \tag{18}$$

$$P_{3t} - c_{3t} = \lambda_{31}(P_{31}x_{3t}) + \lambda_{32}(P_{32}x_{3t}) - P_{33}x_{3t} \tag{19}$$

The market power parameters in the above equations (λ_{ij}'s) are the negative counterparts of the response parameters in (7), (8), and (9): that is, $\gamma_{ij} = -\lambda_{ij}$. To identify these parameters (λ_{ij}'s), it is necessary to specify the derivatives of prices with respect to quantities: P_{12}, P_{13}, P_{21}, P_{23}, P_{31}, and P_{32}. It is though the price derivatives that the degree of product heterogeneity or imperfect substitution becomes observable.

Assuming a market equilibrium in world malting barley, we look to the demand side to identify the quantity derivatives of prices. A cost function approach is oftentimes used due to their mathematical properties such as homogeneity and concavity in solving production problems. However, starting from cost function, we would formulate the problem in price space leading to a solution in quantity space. What we desire is to formulate the problem in quantity space and derive a solution in price space. Therefore, we prefer the dual of the cost function, the distance function. The distance function has the desirable properties such as homogeneity and concavity. The input distance function (Shephard, p.64-78; Färe and Primont, p.19-21) of malting barley by importing countries is defined as

$$D = D(Q,Y) = \sup_{\delta}\{\delta > 0 : Q/\delta) \in L(Y)\} \tag{20}$$

where Q is a (n×1) vector of input quantities; Y is a (1×1) scalar representing malt output; and $L(Y)$ is the input requirement set, which is $L(Y)=\{Q: D(Q,Y) \geq 1\}$. The input distance function measures the proportional reduction in all inputs that are consistent with a target output level. Specifically, δ is the largest scalar value that could be used to divide Q and still produce Y. As is often the case in empirical work, firm-level data are unavailable for this study. Consequently, we aggregate all malt outputs produced by malting barley importing countries and treat malting barley from different sources as different inputs.

To complete the model specification, the distance function is assumed to take the form of a normalized quadratic distance function (Marsh and Featherstone; Holt and Bishop). The normalized quadratic distance function is a semiflexible functional form (Diewert and Wales) and is linear homogeneous, concave, and nondecreasing in inputs, as well as nonincreasing and quasi-concave in output (Shephard, p.207-208; Färe and Primont, p.21, 151-152). The function is given by

$$d^*(Q^*,Y) = b_0 + \sum_{i=1}^{2} b_{\mathrm{i}} x_{\mathrm{i}}^* + \frac{1}{2}\Big(\sum_{i=1}^{2}\sum_{j=1}^{2} b_{\mathrm{ij}} x_{\mathrm{i}}^* x_{\mathrm{j}}^*\Big) + b_3 Y + \sum_{i=1}^{2} b_{\mathrm{iY}} x_{\mathrm{i}}^* Y + \frac{1}{2} b_{\mathrm{Y}} Y^2 \qquad (21)$$

where d^* and x_i^* are normalized distance and input quantities, $d^*=D/x_3$, and $x_i^*=x_{\mathrm{i}}/x_3$, respectively. The inverse demand functions for CWB and ABB are obtained using Gorman's Lemma:

$$P_1^* = b_1 + b_{11}x_1^* + b_{12}x_2^* + b_{1Y}Y \qquad (22)$$

$$P_2^* = b_2 + b_{22}x_2^* + b_{12}x_1^* + b_{2Y}Y \qquad (23)$$

where P_{i}^* is normalized input prices by cost $P_i^* = P_i / \sum_{j=1}^{3} P_j x_j$. Consequently, the cost of producing the target level of output is unity. The third inverse demand function for other exporting countries is dropped to avoid singularity of the error covariance matrix. From the inverse demand equations, the derivatives of prices with respect to quantities can be identified directly. The derived inverse demand function is homogeneous of degree zero in inputs. Homogeneity is realized by the normalization process and symmetry is imposed by setting $b_{ij}=b_{ji}$. Coefficients for the inverse demand response for other exporting countries are recovered using standard demand restrictions.

The derivatives of prices with respect to quantities ($\partial P_i/\partial x_j$) is obtained from the normalized input quantities and parameters in (22) and (23). Then equations (17), (18), and (19) can be rewritten as follows:

$$P_1^* - w_1^* = (\lambda_{12}b_{12} - \lambda_{13}b_{11}x_1^* - \lambda_{13}b_{12}x_2^* - b_{11})x_1^* \qquad (24)$$

$$P_2^* - w_2^* = (\lambda_{21}b_{12} - \lambda_{23}b_{12}x_1^* - \lambda_{23}b_{22}x_2^* - b_{22})x_2^* \qquad (25)$$

$$P_3^* - c_3^* = -\lambda_{31}(b_{11}x_1^* + b_{12}x_2^*) - \lambda_{32}(b_{12}x_1^* + b_{22}x_2^*) - (b_{11}x_1^* + b_{12}x_2^*)x_1^* - (b_{12}x_1^* + b_{22}x_2^*)x_2^* \qquad (26)$$

where w_i^* are the normalized initial payments by cost (See Appendix 2 for derivation). In all, the empirical model consists of a system of five equations: two inverse demand equations [(22) and (23)] and three equations for estimating market power parameters [(24), (25), and (26)].

Data

International statistics, such as the Food and Agriculture Organization Yearbook and World Grain Statistics, report barley trade aggregately instead of separating it into feed and malting barley. Consistent data for malting barley export quantities and prices were available only for Canada and Australia. Multiple data sources include but are not limited to the CWB annual report, the ABB annual report, Australian Commodity Statistics, CIE, Schmitz and Koo, USDA (1997), and Agriculture and Agri-Food Canada’s Bi-weekly

Bulletin. Considering data availability and status change of the ABB, the range of annual data is set between 1975/76 and 1997/98. A thorough description of the procedures for obtaining and developing data for the study is available upon request from the authors.

Estimation Results and Discussion

Generalized Likelihood Tests: The choice of strategic trade policy is crucially dependent upon the strategic variable. While much anecdotal evidence suggests that malting barley STEs compete in differentiated quantities in a manner consistent with Sighn and Vives (fengxia, please add this reference) (i.e. storage behavior, residual feed barley market, implicit subsidies, etc.), it is worthwhile to evaluate such a claim statistically. Therefore, we follow the procedure by Gasmi, Laffont and Voung to test the competing hypotheses of different market structures involving both quantity and price setting strategies. Eight plausible market structures are modeled and nonnested normalized likelihood ratio (LR) tests were used to determine a superior model in pairwise evaluations. The test is based on the generalized likelihood ratio principle and is designed to test the null hypothesis that two competing models adjust the data equally well versus the alternative hypothesis that one model fits better. As Gasmi, Laffont and Voung point out, neither model need be correctly specified for the results of the test to be valid (Gasmi, Laffont, and Voung). The eight market structures included four quantity (price) setting models: Model 1 (Model 5): CWB Lead / ABB follow / other exporting countries follow; Model 2 (Model 6): ABB Lead / CWB follow / other exporting countries follow; Model 3 (Model 7): ABB and CWB jointly lead / other exporting countries follow; and Model 4 (Model 8): ABB, CWB and other exporting countries are in Cournot (Bertran) equilibrium.[iii] In terms of best response parameters γ_{ij} (under price setting, best response parameters are $\partial P_j/\partial P_i$), in leader follower models, all followers' best responses are set equal to zero and leaders' not. In the Cournot and Betrand models, all best response parameters are set as zero.

For each pair of models (M_f, M_g) (f, g =1, 2, …,8; and $f \neq g$), the calculated the likelihood ratio statistic is normalized by

$$N^{\frac{1}{2}}\hat{r}_n = \frac{1}{2}[\sum_{t=1}^{N}(\mu'_{ft}\Sigma_f^{-1}\mu_{ft} - \mu'_{gt}\Sigma_g^{-1}\mu_{gt})^2]^{\frac{1}{2}}$$

where μ_s and Σ_s are the estimated residuals and covariance matrix for model M_s, $s=f, g$. The resulting normalized statistic is asymptotically normally distributed under the null hypothesis of equal fit. When the absolute value of the normalized LR statistic is smaller than the critical level, then the data cannot identify a superior model. If the normalized LR statistic is smaller than the negative critical level, then we conclude that M_g is significantly better; and if it is greater than critical level, then we conclude that M_f is significantly better. The estimation was conducted by using iterative nonlinear SUR method.

The statistical tests based on the normalized LR statistics are given in Table 1 for each pairwise comparison. Table 1 shows that all quantity setting models are significantly better than price setting models in pairwise tests {Fengxia, you have model 8 beating model 7}. This indicates forcefully that some form of quantity setting had prevailed in the world malting barley markets during the study years. This is a critical result because it suggests that rent-shifting is possible through the delayed producer price system and it validates the theoretical model developed for this study.

Although the structural system we estimate can capture any of the four quantity setting games, we do have an opportunity to examine the pairwise tests among models 1 through model 4 (i.e. quantity setting structures), The results are not as clear: no single market structure emerges. Model 1 could not be distinguished as superior or inferior to models 2-4. Models 2 and 4 were found superior to model 3. All we can say at this point is that models 2 and 4 seem most plausible and that model 3 seems least plausible.

Baysian Estimation: The empirical analyses were carried out using both a Bayesian inference framework with restrictions The Bayesian framework allowed parametric restrictions on the λ_{ij}'s and other parameters, as well as imposition of general demand conditions. This approach is a convenient framework from which to obtain bootstrapped confidence intervals for levels of initial payments defined in (14) and (15) and rent shifting defined in (16).

The Bayesian approach is applied because of its advantage in maintaining flexibility by imposing regularity conditions locally and drawing finite sample inferences concerning nonlinear functions of parameters, especially with inequality constraints in our study. Our model can be written in the matrix form:

$$Y = X\beta + \varepsilon \tag{27}$$

where β is a vector of model parameters, Y and X represent data observations, ε ~(0, Σ), and Σ denotes the covariance matrix. Bayesian inference proceeds from the likelihood function and prior information about β and Σ. The posterior probability density function (pdf) $f(\beta, \Sigma|Y, X)$ is proportional to the product of likelihood function and the prior density function. From the posterior pdf $f(\beta, \Sigma|Y, X)$, we can derive the posterior pdf $f(\beta|Y, X)$ (see Judge et al., p.83). However, these kinds of Bayesian inference problems are difficult to integrate and evaluate analytically (Geweke; O'Donnell, Rambaldi, and Doran). To resolve the issue, a Markov Chain Monte Carlo (MCMC) method is commonly applied, which can be used to draw samples from the posterior density $f(\beta|Y, X)$ without having to derive the density itself.

Metropolis-Hastings (M-H) algorithm using the techniques of MCMC simulation is applied to carry out our Bayesian estimation. Tutorial introductions to the M-H algorithm are provided by Chib and Greeberg (1995, 1996). The Metropolis-Hastings algorithm allows the imposition of curvature, monotonicity, and other restrictions during the sample drawing process. And it imposes curvature restrictions locally with computational advantages over importance sampling (Chib and Greenberg, 1996). In our study, we assume a non-informative prior.

The empirical model linked to the theory consists of a system of five equations: two inverse demand equations (22) and (23), and three equations for estimating market power parameters (24), (25), and (26). The Metropolis-Hastings algorithm (see Chib and Greenberg, 1995 and 1996; Griffiths, O'donnell, and Cruz) on this system of equations is carried out in several steps:

Step 1: Set i=0 and specify an arbitrary starting value β^0 that satisfies the constraints of curvature, monotonicity, bounds on market power parameters, and stability conditions from the second order conditions of (4), (5), and (6) as well;

Step 2: Given the current value β^i, use a symmetric transition density $q(\beta^i, \beta^c)$ to generate a value as the next candidate in the sequence, β^c;

Step 3: Use the candidate value β^c to evaluate the constraints of curvature, monotonicity, stability, and bounds on market power parameters. If any constraints are violated, then set u(β^i, β^c)=0 and go to Step 5;

Step 4: let u(β^i, β^c)=min(g(β^c)/g(β^i), 1), where g(β) is the kernel of the marginal density f($\beta|Y, X$);

Step 5: Generate an independent uniform random variable U from the interval [0,1];

Step 6: Let $\beta^{i+1} = \beta^c$ if U< u(β^i, β^c) or $\beta^{i+1} = \beta^i$ otherwise. Set i=i+1 and return to step 2.

Additional assumptions and parameters are needed to specify completely the MCMC process. The burn-in period for the empirical applications was set at 300,000 iterations, which was sufficient to ensure the elimination of the starting value influence and the convergence of the MCMC chain to a stationary distribution.[iv] The post burn-in sample size *m* was set to 300,000 iterations. The iteration process generates a chain with the property that for large i $\beta^{i+1}$is an effective sample from the posterior joint density. Consequently, the sequence β^{i+1}, …, β^{i+m} can be regarded as a sample from f($\beta|Y, X$) that satisfies the constraints of stability, curvature, montonicity, and bounds on market power parameters. In Step 3, the concavity constraint is evaluated by using the maximum eigenvalue of the estimated Hessian matrix. Starting values were chosen that satisfied economic constraints. The choice of transition density q(β^i, β^c) is arbitrary, but it is commonplace to use a multivariate normal distribution (with mean β^i and covariance matrix from the unrestricted nonlinear seemingly unrelated regression estimator). In order to manipulate the rate at which the candidate β^c is accepted as the next value in the sequence, a tuning constant was used to multiply the covariance matrix. A smaller tuning constant increases the acceptance rate but makes new draws look more like old ones and consequently slows down the process. Based on trial and error, the tuning constant is set at 0.01 to make the acceptance rate of approximately 0.50, which is consistent with the commonly recommended acceptance rate (see Chib and Greenberg, 1995).

Parameter Estimates

Confidence intervals for parameter estimates are constructed after the burn-in period. The 90% confidence interval for each parameter was constructed by the percentile method, which requires ranking the estimated parameters and then selecting the 15,000th (5% of total iterations) outcome as the lower critical value and the 285,000th (95% of total iterations) outcome as the upper critical value. If the confidence interval for a parameter estimate contains zero, then the parameter value is not considered significant from zero at the 10% level.

The parameter estimates, along with the upper and lower bounds of the 90% confidence intervals for the Bayesian system, are reported in Table 2. Both b_{11} and b_{22} are significant at the 10% level and negative due to the curvature constraint set during the estimation process. Both output parameters (b_{1y} and b_{2y}) are negative and only b_{1y} is significant. This shows that output of malt has a significant effect on the price of malting barley from the CWB and has an insignificant effect on the price of malting barley from the ABB. However, the effect is very small. Cross-effect parameter b_{12} is insignificant, which suggests that the substitution effects among malting barley from different origins are not significant. Besides product differentiation, one possibility for disguising substitution effects is the effect of geographic distance. (fengxia, what does this mean)

Market power parameters (λ_{ij}) are constrained to lie between -1 and 1. Significance or insignificance of response parameters describes the conduct of STEs and firms in the world malting barley market. If the market power parameter λ_{ij} is not significant, then country i does not consider country j's output change when i makes its decision. If both λ_{ij} and λ_{ji} are not significant, then the two countries are in Cournot competition. The results show that all market power parameters are not significant, which suggests that the CWB, the ABB, and the other exporting countries are in Cournot competition with each other. Given the insignificant substitution effects among malting barley from different origins, it is rational for firms to ignore rival behavior more than when products are homogeneous and we would naturally tend to observe the Cournot-Nash equilibrium.

Initial Payment

Using equations (14) and (15), we tested each STE to see if they had set their initial payments at optimal levels. With linear inverse demand functions, all second derivatives of prices with respect to quantities are zero, which greatly simplifies the matrix *S* (see Appendix 1). By testing the null hypothesis that the optimal markdowns [right hand sides of equations (14) and (15)] were equal to the true values of the markdowns, w_i-c_i, which is the same as testing H_0: $w_i^*-w_i=0$, it could be determined statistically whether the CWB and the ABB set their initial payments at optimal levels. Table 2 contains the bootstrapped estimates of the differences between optimal initial payments and actual payments, along with the upper and lower bounds of the 90% confidence interval for the Bayesian system. Both the CWB and the ABB set their initial payments considerably higher than optimal levels. This implies that while some rent shifting was possible, there is little support for the conclusion that the prepayment system is operating as an effective strategic tool by STEs.

Rent Shifting

A null hypothesis test that STEs could shift rents from other exporting countries, which was based on equation (16), was also conducted by the bootstrap method. Table 3 shows the test results of rent shifting. All values are insignificant. Therefore the hypothesis that STEs did not utilize their initial payments to shift rent cannot be rejected. Combined with the initial payment results from above, a fairly strong conclusion emerges. It does not appear that the prepayment system can be used to shift rent, and, even if it could, it is currently being strictly underutilized. Consequently, the delayed payment system does not provide a statistically validated strategic tool to shift rent, and producers receive no notable benefits from having to wait for full cash payment at the end of the marketing year.

The Wilcoxon Signed Rank Test

To determine if the findings from the bootstrap procedures hold up to additional testing, the Wilcoxon signed rank test was conducted. With 23 pairs of observations of the ranked data, the Wilcoxon signed rank statistic were -4.19726, which has an absolute value greater than the critical value at 5% level for standard normal distribution for both the CWB and the ABB. Therefore, the null hypothesis that there were no differences between optimal and observed initial payments (H_0: $w_i^* - w_i = 0$) should be rejected. Consequently, the left tail alternative, which observed initial payments were higher than optimal levels (H_1: $w_i^* - w_i < 0$), could be accepted. Therefore, the Wicoxon signed rank test suggested that both STEs set their initial payments at higher-than-optimal levels which confirmed our results and conclusion from the Bayesian method.[v]

Summary and Conclusions

The lack of transparency in the pricing and operational activities of STEs has caused WTO members to express concern that certain countries' STEs could circumvent Uruguay Round commitments on export subsidies, domestic support, or market access. Most previous studies have either examined single STE markets or evaluated an STE in isolation from other STEs. Furthermore, in most empirical work the important distinctions between homogeneous and differentiated goods are typically ignored. These are potentially very important issues because strategic trade policy is likely to be quite sensitive to specific market details. In this study, we examined a dual STE market structure of the differentiated world malting barley market in which two STEs (the CWB and ABB) maintained jointly a very large share of the export market. A conceptual two-stage model and an empirical framework were developed to evaluate the market structure and to examine possibilities of rent shifting. In addition, the model provides a framework to test if STEs set their initial payments at optimal levels within the context of their differentiated product. The theoretical model in the study proposed endogenous control of an upstream supply in that STEs chose the initial prices of their raw commodities given that they competed in a downstream market of imperfect substitutes. The decision sequence consisted of a precommitment stage in which STEs chose initial prices followed by an output stage that determined prices, quantities and the trade flows for the two STEs and a group of other exporters.

Based on the conceptual model framework, data, and subsequent empirical results, important conclusions were reached. First, using pairwise tests, we found very strong support that the global malting barley market operated in a quantity setting oligopoly. All pairwise tests between quantity setting and price setting games rejected price setting as the mode of strategic behavior. Second STEs did not have market leadership in the differentiated global malting barley market. Both STEs and other exporting countries were in Cournot competition. Hamilton and Stiegert (2002) also found that the CWB was in Cournot competition with the other export sector in a homogeneous market. But unlike this study, they found support for rent-shifting and leadership outcomes for the STE. Third, the empirical results showed that in world malting barley markets were best characterized as differentiated product markets. When products are not perfect substitutes, firms rationally ignore rival behavior more than when products are the same and we would naturally tend to observe the Cournot –Nash equilibrium in such cases. From the first three conclusions, we found very strong support regarding the conceptual model setup and that the tests for rent shifting could be conducted with some degree of confidence.

Fourth, we found that both STEs were not setting their initial payments at optimal levels and did not shift rent from other exporting countries by utilizing a prepayment system as a precommitment. Indeed, both STEs set their initial payments higher than profit maximization levels, which may in part be attributable to STEs' inefficiency in strategic decision-making and perhaps the existence of a political constraint to lower the initial payments to producers. On the other hand, in the presence of high levels of product differentiation, it may not make much sense to push this as a strategic policy tool compared to other practices such as price discrimination, developing long-term customer relations, etc. In addition, the statistic effect of rent shifting by lowering initial payments was found not significant. In a product-differentiated environment, the realization of rent shifting depends not only on the presupposition of Cournot competition but also on the degree of product differentiation. As a final conclusion, it appears that product differentiation dampened significantly the desire/ability of malting barley STEs to pursue a rent-shifting objective and the initial payment structure market was not found to be used as a strategic trade tool.

REFERENCES

Agriculture and Agri-food Canada. Bi-weekly Bulletin. Various Issues.

Alaouze, C. M., A.S. Watson, and N.H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *American Journal of Agricultural Economics* 60(May 1978): 173-85.

Alston, J. and R. Gray. "State Trading versus Export Subsidies: The Case of Canadian Wheat." *Journal of Agricultural and Resource Economics* 25 (2000): 51-67.

Australian Barley Board. *Annual Report*. Various Issues.

Australian Bureau of Agricultural and Resource Economics. *Australian Commodity Statistics*. Various Issues.

Brander, J., and B. Spencer. "Export Subsidies and International Market Share Rivalry." *Journal of International Economics* 18 (February 1985): 83-100.

Bresnahan, T. "The Oligopoly Solution Concept Is Identified." *Economics Letters* 10 (1982): 87-92.

Brooks, H. "First, Let's Assume We Have a Can Opener: An Analysis of the Economics of a Single American Barley Market." *Canadian Journal of Agricultural Economics* 41 (1993):271-281.

Brooks, H. and T. Schmitz. "Price Discrimination in the International Grain Trade: The Case of Canadian Wheat Board Feed Barley Exports." *Agribusiness* 15 (1999): 313-322.

Canadian Wheat Board. *Annual Report*. Various Issues.

Carter, C. "The Economics of a Single North American Barley Market." *Canadian Journal of Agricultural Economics* 41 (November 1993): 243-255.

Carter, C., R. Loyns, and D. Berwald. "Domestic Costs of Statutory Marketing Authorities: The Case of the Canadian Wheat Board." *American Journal of Agricultural Economics* 80 (May 1998): 313-324.

Carter, C. and V. Smith. "The Potential Impacts of State Trading Enterprises on World Markets: The Exporting Country Case." *Canadian Journal of Agricultural Economics* 49 (2001):429-439.

Center for International Economics. *Review of the Victorian and South Australian Barley Marketing Act 1993*. Final Report Prepared for the Department of Natural Resources and Environment, Victoria and Primary Industries South Australia, 1997.

Chib, S. and E. Greenberg. "Markov Chain Monte Carlo Methods in Econometrics", *Econometric Theory* 12 (1996):409-31.

___. "Understanding the Metropolis-Hastings Algorithm." *The American statistician* 49 (1995): 327-335.

Clark, J. " single Desk Selling by the Canadian Wheat Board: Does It Have an Impact?" *Canadian Journal of Agricultural Economics* 43 (1995): 225-236.

Deodhar, S. and I. Sheldon. "Market Power in the World Market for Soymeal Exports." *Journal of Agricultural and Resource Economics* 22 (1997): 78-86.

Diewert, W. and T. Wales. "A Normalized Quadratic Semiflexible Functional Form". *Journal of Econometrics* 37 (1988):327-342

Dixit, P. and T. Josling. "State Trading in Agriculture: An analytical framework." International Agricultural Trade Research Consortium, Working Paper #97-4, July 1997.

Eaton, J. and G. M. Grossman. "Optimal Trade and Industrial Policy under Oligopoly." *Quarterly Journal of Economics* 101 (May 1986): 383-406.

Färe, R. and D. Primont. *Multi-Output Production and Duality: Theory and Applications*. Kluwer Academic Publishers, Norwell, Massachusetts, 1995.

Fershtman, C., and K.Judd. "Equilibrium Incentives in Oligopoly." *The American Economic Review* 77 (December 1987): 927-940.

Gallop, F. and J. Roberts. " Firm Inerdependence in Oligopolistic Markets." *Journal of Econometrics* 10 (1979): 313-331.

Gasmi, F., J. Laffont, and Q. Vuong. “Econometric Analysis of Collusive Behavior in a Soft-Drink Market.” *Journal of Economics & Management Strategy* 1 (Summer 1992): 277-311.

General Accounting Office. “State Trading Enterprises: Compliance with the General Agreement on Tariffs and Trade.” Report to Congressional Requesters. Report GAO/GGD-95-208, 1995.

_ “Canada, Australia, and New Zealand: Potential Ability of Agricultural State Trading Enterprises to Distort Trade.” Report GAO/NSIAD-96-94, 1996.

Geweke, J. “Bayesian Inference in Econometric Models Using Monte Carlo Integration.” *Econometrica* 57 (Nov.1989): 1317-1339.

Goodwin, B. K and V. H., Smith. “Price Discrimination and International Wheat Markets.” Paper prepared for the Wheat Export Trade Education Committee, September 5, 1995.

Goodwin, B. K and T.C. Schroeder. “Price Dynamics in International Wheat Markets.” *Canadian Journal of Agricultural Economics* 39(1991): 237-254.

Gray, R., A. Ulrich, and A. Schmitz. “A Continental Barley Market: Where Are the Gains?” *Canadian Journal of Agricultural Economics* 41 (1993): 257-270.

Griffiths, W., C. O’Donnell, and A. Cruz. “Imposing Regularity Conditions on a System of Cost and Factor Share Equations.” *The Australian Journal of Agricultural and Resource Economics* 44 (March 2000): 107-127.

Hamilton, S., and K. Stiegert. “Vertical Coordination, Antitrust Law, and International Trade.” *Journal of Law and Economics* 43 (April 2000): 143-156.

______. “An Empirical Test of the Rent-Shifting Hypothesis: The Case of State Trading Enterprises.” *Journal of International Economics* 58 (October 2002): 135-157.

Holt, T., and R. Bishop. “A Semiflexible Normalized Quadratic Inverse Demand System: An Application to the Price Formation of Fish.” *Empirical Economics* 27 (February 2002): 23-47.

Johnson, P., T. Grennes, and M. Thursby. “Trade Models with Differentiated Products.” *American Journal of Agricultural Economics* 61 (February 1979): 120-27.

Judge, G., R. Hill, W. Griffiths, H. Lütkepohl, and T. C. Lee. *The Theory and Practice of Econometrics*. Second Edition. New York: John Wiley & Sons, Inc, 1985.

Kraft, D., W. Furtan, and E. Tyrchniewicz. “Performance Evaluation of the Canadian Wheat Board.” Winnipeg: Canadian Wheat Board, 1996.

Krugman, P. R. "Industrial Organization and International Trade." In *Handbook of Industrial Organization*, Vol. II. R. Schmalensee, and R. D. Willig ed., Northholland, Amsterdam, 1989.

Marsh, T. "Elasticities for U.S. Wheat Food Use by Class." Selected Paper, Australian Agricultural and Resource Economics meetings, 2003.

Marsh, T., and A. Featherstone. "Inverse Price Relationship by Wheat Class." Selected Paper, American Agricultural Economics Association, 2003.

McCalla, A.F. "A Duopoly Model of World Wheat Pricing." *Journal of Farm Economics 48* (August 1966): 711-727.

O'Donnell, C., A. Rambaldi, and H. Doran. "Estimating Economic Relationships Subject to firm- and Time-Varying Equality and Inequality Constraints. *Journal of Applied Econometrics* 16 (June 2001): 709-726.

Rosen, J. "Existence and Uniqueness of equilibrium Points for Concave N-Person Games." *Econometrica* 33(1965): 520-534.

Schmitz, A., R. Gray, T. Schmitz and G. Storey. "The CWB and Barley Marketing-Price Pooling and Single-Desk Selling." The Canadian Wheat Board Publications. January 1997.

Schmitz, T., and R. Gray. "State Trading Enterprises and Revenue Gains from Market Power: The Case of Barley Marketing and the Canadian Wheat Board." *Journal of Agricultural and Resource Economics* 25 (December 2000): 596-615.

Schmitz, T. and W. Koo. "An Economic Analysis of International Feed and Malting Barley Markets: An Econometric Spatial Oligopolistic Approach." Agricultural Economics Report No. 357, September 1996. North Dakota State University.

Shephard, R.W. *Theory of Cost and Production Functions*. Princeton University Press, Princeton, New Jersey, 1970.

Smith, V. H., B. Goodwin, and M. Holt. "Price Leadership in International Wheat Markets." Paper prepared for the Wheat Export Trade Education Committee, September 5, 1995.

Spriggs, J., M. Kaylen, and D. Bessler. "The Lead-Lag Relationship between Canadian and U.S. Wheat Prices." *American Journal of Agricultural Economics* 64 (August 1982): 569-572.

Stiegert, K., and J. Blanc. "Japanese Demand for Wheat Protein Quantity and Quality." *Journal of Agricultural and Resource Economics* 22 (July 1997): 104-119.

U.S. Department of Agriculture (USDA), Economic Research Service. *Agricultural Outlook*. November 1997.

___. "State Trading Enterprises in World Agricultural Trade." Agriculture in the WTO/WRS-98-44. December 1998.

Wilson, W., and D. Johnson. "North American Malting Barley Trade: Impacts of Differences in Quality and Marketing Costs." *Canadian Journal of Agricultural Economics* 43 (1995): 335-353.

Table 1 Adjusted LR Statistics for Model Selection

$M_f \backslash M_g$	M_2	M_3	M_4	M_5	M_6	M_7	M_8
M_1	-0.17186	1.36095	-0.18916	193.26396	201.01865	201.69934	200.64064
M_2		2.91179	0.02330	193.88048	201.49992	202.34139	201.26197
M_3			-2.27447	196.09928	205.38926	207.81623	204.42487
M_4				191.80673	199.17858	200.04084	199.02622
M_5					12.33784	17.71499	92.82507
M_6						17.54904	77.28428
M_7							-24.48110

The models are: Model 1: Stackelberg with CWB quantity leadership; Model 2: Stackelberg with ABB quantity leadership; Model 3: Stackelberg with ABB and CWB joint quantity leadership; Model 4: Cournot; Model 5: Stackelberg with CWB price leadership; Model 6: Stackelberg with ABB price leadership; Model 7: Stackelberg with ABB and CWB joint price leadership; Model 8: Bertrand equilibrium.

Table 2 Estimations by Bayesian Approach

		90% Confidence Interval	
	Estimations	Upper Critical Value	Lower Critical Value
b_1	0.004569	0.006110	0.002872
b_2	0.000981	0.002502	-0.000444
b_{11}	-0.000314	-0.000148	-0.000468
b_{12}	0.000032	0.000105	-0.000036
b_{22}	-0.000077	-0.000010	-0.000149
b_{1y}	-0.000220	-0.000120	-0.000309
b_{2y}	-0.000040	0.000050	-0.000130
λ_{12}	-0.010489	0.892883	-0.903652
λ_{13}	-0.003419	0.908939	-0.890538
λ_{21}	-0.009258	0.898162	-0.899115
λ_{23}	-0.001981	0.899945	-0.902355
λ_{31}	0.008496	0.900737	-0.897575
λ_{32}	0.011256	0.900635	-0.895491

Burn in period=300,000. Sample size=300,000.

Table 3 Estimates for Hypothesis Test H_0: $w_i*-w_i=0$ by Bayesian Method.

	Mean ($/1,000 tonnes)	90% Confidence Interval Upper Critical Value	 Lower Critical Value
$w_1^*-w_1$	-698.333727	-279.425133	-1173.773703
$w_2^*-w_2$	-854.334639	-697.353257	-1101.998755

Table 4 Hypothesis Test that STEs Could Shift Rents from Other Exporting Countries by Bayesian Method.

	Mean	90% Confidence Interval Upper Critical Value	 Lower Critical Value
$\partial\pi_2/\partial w_1$	-36.456899	143.316877	-302.079605
$\partial\pi_3/\partial w_1$	-182.203001	293.554632	-839.634976
$\partial\pi_1/\partial w_2$	-414.891691	608.167068	-1044.391131
$\partial\pi_3/\partial w_2$	-752.743429	2094.303887	-2564.479655

APPENDIX 1

The ratios of marginal effects $\partial x_i/\partial w_j$ in (14) and (15) can be expressed as

$$\frac{\frac{\partial x_2}{\partial w_1}}{\frac{\partial x_1}{\partial w_1}} = \frac{(S_6S_7 - S_4S_9)/|S|}{(S_5S_9 - S_6S_8)/|S|} = \frac{S_6S_7 - S_4S_9}{S_5S_9 - S_6S_8}$$

$$\frac{\frac{\partial x_3}{\partial w_1}}{\frac{\partial x_1}{\partial w_1}} = \frac{(S_4S_8 - S_5S_7)/|S|}{(S_5S_9 - S_6S_8)/|S|} = \frac{S_4S_8 - S_5S_7}{S_5S_9 - S_6S_8}$$

$$\frac{\frac{\partial x_1}{\partial w_2}}{\frac{\partial x_2}{\partial w_2}} = \frac{(S_3S_8 - S_2S_9)/|S|}{(S_1S_9 - S_3S_7)/|S|} = \frac{S_3S_8 - S_2S_9}{S_1S_9 - S_3S_7}$$

$$\frac{\frac{\partial x_3}{\partial w_2}}{\frac{\partial x_2}{\partial w_2}} = \frac{(S_2S_7 - S_1S_8)/|S|}{(S_1S_9 - S_3S_7)/|S|} = \frac{S_2S_7 - S_1S_8}{S_1S_9 - S_3S_7}$$

In the above equations, the S_i's are the submatrices in the matrix S defined as

$$S = \begin{pmatrix} S_1 & S_2 & S_3 \\ S_4 & S_5 & S_6 \\ S_7 & S_8 & S_9 \end{pmatrix}$$

$$= \begin{pmatrix} 2P_{11} + (\gamma_{12}P_{12} + \gamma_{13}P_{13}) + x_1(P_{111} + \gamma_{12}P_{121} + \gamma_{13}P_{131}) & P_{12} + x_1(P_{112} + \gamma_{12}P_{122} + \gamma_{13}P_{132}) & P_{13} + x_1(P_{113} + \gamma_{12}P_{123} + \gamma_{13}P_{133}) \\ P_{21} + x_2(\gamma_{21}P_{211} + P_{221} + \gamma_{23}P_{231}) & 2P_{22} + (\gamma_{21}P_{21} + \gamma_{23}P_{23}) + x_2(\gamma_{21}P_{212} + P_{222} + \gamma_{23}P_{232}) & P_{23} + x_2(\gamma_{21}P_{213} + P_{223} + \gamma_{23}P_{233}) \\ P_{31} + x_3(\gamma_{31}P_{311} + \gamma_{32}P_{321} + P_{331}) & P_{32} + x_3(\gamma_{31}P_{312} + \gamma_{32}P_{322} + P_{332}) & 2P_{33} + (\gamma_{31}P_{31} + \gamma_{32}P_{32}) + x_3(\gamma_{31}P_{313} + \gamma_{32}P_{323} + P_{333}) \end{pmatrix}$$

with the notation that $P_{ijk} = \partial^2 P_i/\partial x_j \partial x_k$ (i, j, k=1, 2, 3, respectively).

Appendix 2

From the inverse demand function, the price flexibilities are

$$f_{\mathrm{ij}} = \frac{b_{\mathrm{ij}} x_{\mathrm{j}}^{*}}{P_{\mathrm{i}}^{*}} = \frac{\partial P_{\mathrm{i}}}{\partial x_{\mathrm{j}}} \frac{x_{\mathrm{j}}}{P_{\mathrm{i}}}$$

$$\Rightarrow P_{\mathrm{ij}} = \frac{\partial P_{\mathrm{i}}}{\partial x_{\mathrm{j}}} = \frac{b_{\mathrm{ij}} x_{\mathrm{j}}^{*}}{P_{\mathrm{i}}^{*}} \frac{P_{\mathrm{i}}}{x_{\mathrm{j}}} = b_{\mathrm{ij}} \frac{\frac{x_{\mathrm{j}}}{x_3}}{\frac{P_{\mathrm{i}}}{\mathrm{cost}}} \frac{P_{\mathrm{i}}}{x_{\mathrm{j}}} = b_{\mathrm{ij}} \frac{\mathrm{cost}}{x_3} \qquad (\mathrm{i}, \mathrm{j} = 1, 2)$$

From homogeneity, $f_{13} = -f_{11} - f_{12}$.

$$f_{13} = \frac{\partial P_1}{\partial x_3} \frac{x_3}{P_1} \Rightarrow P_{13} = \frac{\partial P_1}{\partial x_3} = f_{13} \frac{P_1}{x_3} = (-f_{11} - f_{12}) \frac{P_1}{x_3}$$

$$= (-b_{11} \frac{x_1^{*}}{\frac{P_1}{\mathrm{cost}}} - b_{12} \frac{x_2^{*}}{\frac{P_1}{\mathrm{cost}}}) \frac{P_1}{x_3}$$

$$= (-b_{11} x_1^{*} - b_{12} x_2^{*}) \frac{\mathrm{cost}}{x_3}$$

Similarly,

$$P_{23} = \frac{\partial P_2}{\partial x_3} = f_{23} \frac{P_2}{x_3} = (-f_{21} - f_{22}) \frac{P_2}{x_3} = (-b_{12} x_1^{*} - b_{22} x_2^{*}) \frac{\cos t}{x_3}$$

Apply Young's Theorem to normalized quadratic distance function,

$$P_{31=} \frac{\partial P_3}{\partial x_1} = \frac{\partial P_1}{\partial x_3} = P_{13}$$

$$P_{32} = \frac{\partial P_3}{\partial x_2} = \frac{\partial P_2}{\partial x_3} = P_{23}$$

Since

$$f_{33} = -f_{31} - f_{32} = -f_{13} P_1^{*} \frac{x_1^{*}}{P_3^{*}} - f_{23} P_2^{*} \frac{x_2^{*}}{P_3^{*}}$$

$$= -(-f_{11} - f_{12}) P_1^{*} \frac{x_1^{*}}{P_3^{*}} - (-f_{21} - f_{22}) P_2^{*} \frac{x_2^{*}}{P_3^{*}}$$

$$= (b_{11}\frac{x_1^*}{P_1^*} + b_{12}\frac{x_2^*}{P_1^*})P_1^*\frac{x_1^*}{P_3^*} + (b_{12}\frac{x_1^*}{P_2^*} + b_{22}\frac{x_2^*}{P_2^*})P_2^*\frac{x_2^*}{P_3^*}$$

$$= (b_{11}x_1^* + b_{12}x_2^*)\frac{x_1^*}{P_3^*} + (b_{12}x_1^* + b_{22}x_2^*)\frac{x_2^*}{P_3^*}$$

We are able to derive P_{33} from f_{33}.

$$f_{33} = \frac{\partial P_3}{\partial x_3}\frac{x_3}{P_3} \Rightarrow P_{33} = \frac{\partial P_3}{\partial x_3} = f_{33}\frac{P_3}{x_3}$$

$$= [(b_{11}x_1^* + b_{12}x_2^*)\frac{x_1^*}{P_3^*} + (b_{12}x_1^* + b_{22}x_2^*)\frac{x_2^*}{P_3^*}]\frac{P_3}{x_3}$$

$$= [(b_{11}x_1^* + b_{12}x_2^*)x_1^* + (b_{12}x_1^* + b_{22}x_2^*)x_2^*]\frac{\text{cost}}{x_3}$$

Substituting P_{ij} (i,j=1,2,3) into (17), (18), and (19), dividing both sides by cost, and combining x_{i} with x_3 into x_{i}* yields (24), (25), and (26).

End Notes

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[i] Other forms of rent-shifting are certainly possible, e.g., Fershtman and Judd demonstrate market rent-shifting is possible through internal incentive systems.

[ii] Prior to 2000/01, there was only price pooling for the CWB. Beginning in the 2000/01 crop year, the CWB introduced new payment options for farmers, which include fixed price contracts for wheat, durum, and feed barley, basis price contract for wheat, the early payment option, and the guaranteed delivery contract for feed barley. The fixed price contract for selected barley (malting barley) is offered in 2004. Given studying period of 1975/76 to 1997/98, the paper did not provide more information on the payment policies and options provided by the CWB. For ABB, there was only price pooling during the study period.

[iii] Linear demand functions in price setting models were derived from the normalized quadratic cost function. During estimation, symmetry, homogeneity, and curvature were also imposed.

[iv] In the preliminary analysis a host of different MCMC chains with alternative starting values were used to check convergence of the parameter estimates.

[v] To further test the robustness of the Bayesian results, an iterative Nonlinear SUR estimation procedure was used on the five equation model [equations (22)-(26)]. Nonlinear SUR and the Bayesian results were similar in the sense that all market power parameters were insignificant, optimal initial payments were lower than observed values, and rent shifting effects were insignificant. However, they differ in magnitudes and significance of some parameter estimates (full details are available from the authors).