Food Marketing Policy Center

Price Discrimination in the
Context of Vertical Differentiation:
An Application to Canadian Wheat Exports

by Nathalie Lavoie

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University of Connecticut
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Preface

This study examines the ability of the Canadian Wheat Board (CWB) to price discriminate in bread wheat exports. This study models wheat as a vertically differentiated intermediate good and modifies the model of vertical differentiation by Mussa and Rosen to the realities of wheat import demand. The conceptual model isolates the bases of price discrimination and demonstrates that the CWB's ability to exploit cost differences in pricing depends on the extent of the differentiation between Canadian and U.S. wheat.

This model is implemented using monthly confidential price data provided by the CWB for exports to Japan, the United Kingdom, and two markets aggregating remaining exports through Canada's west and east coasts, for 1982-1994. The data indicate that the CWB charges different prices to different countries for wheat of the same grade and protein content. Results from the model indicate that the price difference between any two markets is not completely explained by elements of perfect competition. However, the evidence is mixed regarding the ability of the CWB to utilize all the instruments available to price discriminate. Thus, the CWB's pricing strategy may be more complex and dynamic than the prescription for static producer surplus maximization derived in this study.

Key words:

1. Introduction

In microeconomics textbooks the wheat industry is often used to illustrate an industry characterized by product homogeneity and perfect competition. This study challenges this view by investigating the presence of price discrimination in a differentiated wheat industry. Different wheat "classes" are used in flour destined for the production of raised breads, flat breads, noodles, cookies and cakes, pasta, etc. Not only do wheat classes differentiate wheat, but within those classes wheat is also differentiated by quality. As emphasized in the studies conducted by Mercier (1993) and Stephens and Rowan (1996), Canadian and Australian wheat are often considered by importers to be of better quality than U.S. wheat.

With product differentiation, the potential exists for a large seller to exert market power through price discrimination. Interestingly, both Canada and Australia export wheat through a marketing board which has been given the sole right to export. These two marketing boards are also considered state-trading enterprises (STEs).[1]

STEs are nowadays controversial institutions and have been challenged internationally and domestically. Internationally, the criticisms focus on the ability of STEs to engage in unfair trade practices and distort worldwide trade (GAO, 1996). In fact, under the next round of the WTO negotiation, the United States hopes to end the exclusive export rights and government financial backing of STEs (Miner, 2001). Domestically, it is the benefit provided by STEs to wheat producers that is under question both in Canada and in Australia.

In the context of those challenges, prior research has sought to examine the benefits and costs of the CWB (Kraft, Furtan and Tyrchnewicz (KFT), 1996; Carter and Loyns, 1996) and of the AWB (Piggott, 1992; Ryan, 1994; Booz, Allen and Hamilton, 1995). Proponents of the CWB and AWB have examined whether the CWB and AWB can market wheat at a premium over the price of comparable wheat from competitors. KFT and Ryan found that the CWB and AWB, respectively, obtained a price premium in the international market due to their ability to price discriminate. However, it is not clear from those studies to what extent the measured price premia can be attributed to the higher quality of Canadian and Australian wheat.

Opponents of the CWB have argued that the CWB over-delivers on protein content and use "other lucrative contract terms which utilize discriminatory pricing and are the equivalent of export subsidies" (North Dakota Wheat Commission (NDWC), 2000). The over-delivery of protein is viewed as an inefficiency (Carter, Loyns, and Berwald, 1998) or a form of predatory pricing (NDWC, 2000). These arguments confirm the importance of considering wheat heterogeneity when evaluating the performance of organizations such as the CWB and the AWB.

The objective of this study is to examine the ability of the CWB to price discriminate in a manner that maximizes producer surplus while treating wheat as a vertically differentiated intermediate good. This study contributes to the literature on wheat trade by modeling jointly the presence of imperfect competition, product differentiation, and STE competing against private firms. The new empirical organization approaches to examine market power have focused on consumer goods and are not directly applicable to intermediate inputs like wheat. This study modifies the model of quality differentiation developed by Mussa and Rosen (1978) to the realities of bread wheat import demand. The Pricing-to-Market literature examine how movements in exchange rate can be used to price discrimination in international trade. In this study, I consider movements in any variable that causes a price wedge between the exporters' and the importers' price, such as ocean freight rates, import duties and subsidies, and exchange rates, as "instruments" of price discrimination. The conceptual model isolates the effect of various instruments of price discrimination and demonstrates that the CWB's ability to exploit fluctuations in those instruments in pricing depends on the extent of the differentiation between Canadian and U.S. wheat. The empirical analysis of price discrimination uses confidential price data on bread wheat exports by the CWB.

[1] According to the U.S. General Accounting Office (GAO), "STEs are generally considered to be enterprises that are authorized to engage in trade and are owned, sanctioned, or otherwise supported by the government" (GAO, 1996).

2. Canadian and U.S. Wheat Industries

The United States and Canada export the bulk of high-protein hard wheat, the type of wheat used in raised bread production. Whereas most of the Canadian wheat production consists of Canada Western Red Spring (CWRS) wheat, a class of wheat used in bread making, the United States produces a larger number of wheat types. Two other important differences between the Canadian and U.S. wheat industries are their marketing and variety control systems.

Exports of U.S. wheat are dominated by the activities of a few multinational firms. In contrast, all Western Canadian wheat going for export or for domestic processing is marketed by the CWB. The CWB has the stated objective to market "quality products and services to maximize returns to western Canadian grain producers" (CWB, 2001). The CWB markets wheat and barley on behalf of farmers and returns to the farmers all the net proceeds from the sales, minus operating and administration costs, as a pooled price.

Variety control in Canada is done by including varietal standards in official grade definitions and a kernel visual distinguishability requirement. For example, the Neepawa variety is the varietal standard for CWRS wheat. For a new CWRS wheat variety to be registered and placed on the market, it must not only be of equal quality to Neepawa, or better, but also be visually different from wheat in other classes. Western Canadian farmers are not allowed to grow non-registered and indistinguishable wheat varieties. This system enables wheat to be segregated by classes reflecting different end-use purposes and ensures a minimum intrinsic wheat quality.

In contrast to Canada, the U.S. varietal development and release system is unregulated. New varieties are developed and released by both public and private firms. According to Dahl and Wilson (1997), this difference in variety control policy has resulted in twice as many releases of new hard red spring varieties in the United States as in Canada. American wheat producers are free to choose among the wheat varieties available on the seed market. Because different varieties within each class have different end-use and agronomic quality, such as high yield, disease resistance, etc., producers may not always choose varieties with good end-use quality. The difference in the variety control system between Canada and the United States certainly contributes to the higher quality recognition of Canadian wheat relative to U.S. wheat.

3. Wheat Quality

Quality and quantity of flour produced from a given quantity of wheat depend on the physical and intrinsic quality of the wheat kernels. Protein content is the single most important predictor of the end-use potential of wheat (Williams, 1997). For raised-bread baking, protein level directly influences loaf volume and crust and crumb texture. Up to about 13 percent protein is beneficial for raised breads, because higher protein will result in complications in mixing and fermentation (Williams, 1997). Wheat with more than 13 percent protein is normally used in blends with wheat of lower protein content. Protein quality, which varies by wheat varieties, is just as important as protein quantity. If two flours, coming from two different wheat varieties but with the same protein content, produce two different loaf volumes, everything else constant, their protein is said to be of different quality (Tweed, 1993).

The results of two surveys of importers of bread wheat (Mercier, 1993 and Stephen and Rowan, 1996) show that important wheat quality characteristics differ by importing countries and importer. However, consistency in quality and intrinsic quality, especially the level and consistency of protein quantity and quality, emerge as important characteristics for importers in general. In Mercier (1993) protein quantity was rated the most important quality characteristics in wheat purchasing decision, followed by gluten (protein) quality, moisture content, and the quantity of nonmillable material. Canada and Australia were recognized to export higher overall quality (physical and intrinsic) than the United States. The main concern with U.S. bread wheat was the variability in protein quality within and between shipments and the difficulty of the United States "to provide the level of protein that buyers expect" (Mercier, 1993, p.19).

4. Conceptual Model of Trade of a Vertically Differentiated Intermediate Good

Price discrimination takes place when different markups exist for sales to different consumers. In an oligopoly setting, as is the case for international wheat trade, price discrimination is usually explained by product or brand heterogeneity, i.e., horizontal product differentiation (Katz, 1984, Borenstein, 1985).[2] In the context of this study, it is vertical product differentiation that enables price discrimination. In other words, the CWB may be able to charge different prices in different markets because Canadian wheat is recognized to be of higher quality than U.S. wheat and different markets may have different willingness to pay for a higher quality.

Schmitz et al. (1997) and Brooks and Schmitz (1999) examined the ability of the CWB to price discriminate in the feed barley market by testing whether the prices between any market pair is statistically different. Both studies had access to CWB data and found evidence of price discrimination between 1980-81 and 1994-95. However, this approach does not take into account other factors, such as intrinsic quality differences, which could explain the price difference.

In what follows, I derive an empirical test of price discrimination from a conceptual model of the supply and demand for vertically differentiated intermediate goods. The approach consists in estimating a reduced form equation containing variables that explain prices under imperfect competition but not under perfect competition.

The demand side of the model is characterized by heterogeneous importers who demand wheat that is vertically differentiated. Goods that are purely vertically differentiated are rare. Most goods contain a bundle of characteristics and are differentiated both horizontally and vertically. However, when interested in the quality aspect of a product, modeling is greatly simplified by considering quality as a summary index of the quantity of product characteristics. Using quality as a summary index of a product's characteristics is a reasonable assumption when consumers generally rank the differentiated products in the same order of quality. Treating bread wheat as a vertically differentiated product is reasonable according to the surveys conducted by Mercier (1993) and Stephen and Rowan (1996), where many countries agree that Canadian wheat is of better quality than U.S. wheat.

Vertical differentiation models have been developed primarily for consumer goods and have rarely been used or modified for intermediate goods (Lavoie, 2001). One exception is a model of differentiation in the sweetener industry (Cooper, Giraud-Héraud, and Réquillart, 1995). The model of vertical differentiation developed by Mussa and Rosen (1978) has the characteristics sought for this study. The next section modifies the Mussa-Rosen approach to the realities of the demand for high-protein wheat.

4.1 Demand side

Assume that two countries each export a differentiated commodity – wheat – to two markets. Assume further that wheat is differentiated by quality only. Country H (Canada) produces wheat of high quality k_H and country L (United States) produces wheat of lower quality k_L, i.e., $k_H > k_L$.

Suppose that wheat is imported in each market for processing into an end-product, e.g., flour. Moreover, it is assumed that importing country m (m = 1, 2) produces wheat domestically of quality k_d^m, which is lower than the quality of both foreign wheats. Millers, in each country, differ according to their desired end-product qualities, k^m. The quality of the end-product for the millers in market m ranges in the interval $k^m \in [s_m, K_m]$, where s_m can be viewed as a minimum quality standard in market m, and $K_m = s_m + 1$.

Finally, in both markets the maximum desired end-product quality is higher than the quality of the domestic wheat (in end-product quality equivalent terms), but lower than the quality of foreign wheat. That is, $k_d^m < K_m < k_L < k_H$. The end-product quality of a specific miller may or may not be below the domestic wheat quality. If the end-product quality of a miller in market m is higher than the domestic wheat quality $(k_d^m < k^m)$, it must import wheat of quality k_H or k_L to blend in the production of the end product. This situation applies well to high-protein hard wheat. Most importing countries produce wheat domestically that is not high enough in protein

[2] There are two types of product differentiation. Products are "horizontally" differentiated when they possess different characteristics, for example, a blue car versus a red car. Some consumers will prefer one car versus another, but all consumers do not agree on which car is preferred because they have different preferences for color. Products are "vertically" or quality differentiated when they differ by the level of a certain characteristics, where more of a given characteristic is better. For example, a car with more fuel efficiency is preferred to an identical car with less fuel efficiency. Under vertical differentiation, all consumers would choose the higher quality good if it was sold at the same price as the lower quality good.

content to produce flours used in the production of raised bread. Thus, domestic wheat must be blended with Canadian or U.S. hard wheat, which have higher protein content.

Domestic and foreign wheat must be blended according to specific proportions depending on the quality of domestic wheat, the quality of foreign wheat and the desired end-quality. Moreover, the wheat input is combined with other inputs such as labor and capital to produce flour. Therefore, we can imagine a Leontief production function of the type:

$$y^m = \min\left\{\min\left[\frac{q_i}{a(k_i,k_d^m,k^m)}, q_d\right], \frac{h(S)}{b(k_i,k_d^m,k^m)}\right\}, \tag{1}$$

where y^m is the flour output of a typical firm in market *m*, q_i is the quantity of imported wheat *i* (i=*H*, *L*), and q_d is the quantity of domestic wheat. The parameter $a(k_i,k_d^m,k^m)$ is the ratio of foreign wheat relative to domestic wheat, *S* is a vector of other inputs, and $b(k_i,k_d^m,k^m)$ is the ratio of wheat input to other inputs. Other inputs *S* do not have to be used in fixed proportions with one another in *h(S)*.

In this formulation wheat *H* and wheat *L* are considered to be perfect substitutes in the sense that the higher quality wheat is considered to be more "productive" in output production. More specifically, the ratios of foreign to domestic wheat, $a(\cdot)$, and wheat input to other input, b(·), decrease with the quality of the imported and domestic wheat. The ratios increase with the end-product quality. To incorporate these notions in a tractable way, assume that the parameters $a(\cdot)$ and $b(\cdot)$ can be expressed as

$$a(k_i,k_d^m,k^m) = \frac{k^m}{k_i k_d^m}$$

and

$$b\left(k_i,k_d^m,k^m\right) = \frac{\left(k^m\right)^2}{k_i k_d^m}.$$

The functional form assumed for the ratio of wheat input to other inputs indicate that the quantity of processing inputs increases at an increasing rate as the end-product quality (k^m) increases.

Assume that flour millers in market *m* each have a contract for y^{*m} quantity of flour to be delivered. Moreover, each miller produces a different end-product quality or, said differently, a different type of flour. The flour miller must choose between wheat H and wheat L to minimize costs. The miller therefore faces the following problem:

$$\min_{q_H,q_L,q_d,S} p_H^m q_H + p_L q_L + p_d q_d + wS \quad s.t. \quad y^{*m} = \min\left\{\min\left[\frac{q_i}{a(k_i,k_d^m,k^m)}, q_d\right], \frac{h(S)}{b(k_i,k_d^m,k^m)}\right\},$$

where p_H^m is the price of wheat *H* in market *m*, *w* is a vector of other input prices, and *i* = *H*, *L*. For notational simplicity, from now on I replace *a(·)* and *b(·)* by a_i and b_i, respectively. Flour millers minimize costs by combining inputs such that:

$$y^{*m} = \frac{q_i}{a_i} = q_d = \frac{h(S)}{b_i}. \tag{2}$$

Therefore, the cost from using wheat *i* for a typical miller in market *m* is given by:

$$C_i^m(p_i^m, p_d, w, k_i, k_d^m, k^m, y^{*m}) = p_i^m y^{*m} a_i + p_d y^{*m} + G^m(w, y^{*m} b_i),\ i{=}H,L.$$

$G^m(w, y^{*m} b_i)$ represents the non-farm product processing costs and is the result of minimizing costs with respect to the choice of the processing inputs, *S*. Assume that $G^m(w, y^{*m} b_i) = g^m(w) y^{*m} b_i$, i.e., constant returns to scale.

Some millers may choose to purchase none of wheat *H* or *L*. In this case, they may purchase another class of wheat produced domestically or imported. An example is the Hard Red Winter wheat class produced by the United States. Allowing a firm to use another class of wheat of intrinsic quality k_o (where $k_o < k_L < k_H$) is similar to having an "outside good" in the standard model of vertically differentiated products. The outside good guarantees that if the prices of both wheat *H* and *L* increase in the same proportions, their consumption decreases.

A flour miller in market *m* with end-product quality k^m will choose to use the type of wheat with the lowest cost. Thus, substituting the expressions for a_i, b_i, and the processing cost, the cost function of a typical miller in market *m* can be expressed as:

$$C_i^m(p_H^m, p_L, p_d, w, k_H, k_L, k_d^m, k^m, y^{*m}) =$$
$$y^{*m}\left(p_d + \min\left[p_H^m \frac{k^m}{k_H k_d^m} + g^m(w)\frac{(k^m)^2}{k_H k_d^m},\ p_L \frac{k^m}{k_L k_d^m} + g^m(w)\frac{(k^m)^2}{k_L k_d^m},\ p_o + g^m(w)\frac{(k^m)^2}{k_o k_d^m} \right]\right).$$

In each market millers are distributed uniformly according to their end-product qualities on $k^m \in [s_m, K_m]$. There are two indifferent millers in a given market *m*.[3] The miller with final product quality

$$k_{HL}^m = \frac{(p_H k_L - p_L k_H)}{g^m(w)(k_H - k_L)},$$

is indifferent between buying wheat *H* and *L* because they generate the same cost. [4] The miller with final product quality

$$k_{LO}^m = \frac{(p_L k_O - p_O k_L)}{g^m(w)(k_L - k_O)},$$

is indifferent between buying wheat *L* and the outside good. Millers with a final product quality greater than k_{HL}^m will choose to import wheat *H* because the cost of using wheat *H* is lower than the cost of using wheat *L*, or because:

[3] There are two indifferent millers if the intrinsic quality of the outside good is sufficiently low and if the price to quality ratio of the outside good is sufficiently high. If this is not the case, the low-quality wheat will not be purchased in a given market and there will be only one indifferent miller between the high-quality wheat and the outside good. It is assumed that this condition holds.

[4] It is assumed that $k_{HL}^m < K_m$ so that a positive quantity of high-quality wheat is imported in each market. For non-zero imports of high-quality wheat, manipulations of equation 3 indicates that the minimum standard of end-product quality and the marginal processing cost ($g^m(w)$) must be high enough.

$$p_H^m - p_L \frac{k_H}{k_L} < k^m g^m(w)\left(\frac{k_H - k_L}{k_L}\right). \tag{3}$$

The above expression says that for a flour miller to import the wheat *H* rather than wheat *L*, the decrease in processing cost must outweigh the increase in the quality-adjusted procurement cost.

The demand for wheat *H* and *L* can be found by summing the quantity purchased by each miller. The demand for the high-quality good in both markets can therefore be expressed as:

$$D_H^1\left(p_H^1, p_L, w, K_1, k_H, k_L, k_d^1, Y^{*1}\right) = \frac{Y^1}{2k_H k_d^1}\left(\left(K_1\right)^2 - \left(\frac{\left(p_H^1 k_L - p_L k_H\right)}{g^1(w)(k_H - k_L)}\right)^2\right) \tag{4}$$

$$D_H^2\left(p_H^2, p_L, w, K_2, k_H, k_L, k_d^2, Y^{*2}\right) = \frac{Y^2}{2k_H k_d^2}\left(\left(K_2\right)^2 - \left(\frac{\left(p_H^2 k_L - p_L k_H\right)}{g^2(w)(k_H - k_L)}\right)^2\right), \tag{5}$$

where, Y^1 and Y^2 are the summation of the quantity of output contracted by each miller in market 1 and 2 respectively. These demand equations are appealing because they demonstrate how the qualities of the domestic and foreign wheat, as well as end-product quality, interact to determine the quantity demanded from each exporter. The demands for wheat *L* can be found similarly.

4.2 Supply Side

The wheat marketing systems of the two exporting countries differ. Wheat *H* is exported through a marketing board (the CWB). Given that the CWB has as stated objective to sell wheat at the best possible price and return to farmers the net proceeds from sales, the objective function for this study is the maximization of producer surplus subject to a quantity constraint Q_H, which correspond to a given harvest of wheat. Producer surplus consists of sales revenues to the two markets minus marketing costs, where marketing costs corresponds to the costs of wheat transportation to export position in Canada, elevation, storage, etc. In contrast, profit-maximizing firms market wheat *L*. Assume that firms in country *L* engage in price competition among themselves. Each firm in country *L* sells a product that is non-differentiated from other firms in country *L*. Therefore, as long as there is more than one firm selling wheat of quality k_L, the price at which wheat *L* is exported to both markets is the price, p_L, corresponding to the intersection of the total demand wheat *L* with the supply.[5] The equilibrium price can be found by equating total demand with the fixed supply of low-quality wheat Q_L as follows:

$$D_L^1\left(p_H^1, p_L\right) + D_L^2\left(p_H^2, p_L\right) = Q_L, \tag{6}$$

and solving for p_L,

$$p_L = p_L\left(p_H^1, p_H^2, Q_L\right),$$

where $D_L^m(\cdot)$ is the demand of market *m* for wheat *L*. Wheat is assumed to be produced once a year and there is no year-to-year storage.

We seek a Nash equilibrium in prices where the marketing board is also assumed to engage in price competition with the sellers of the low-quality wheat. Because the marketing board sells a product that is differentiated from that

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[5] This treatment of U.S. wheat exports is consistent with the results of Thursby (1988) and Arnade and Pick (1999) who found limited or no support for market power

of its competitors, it can charge prices that are different from the competitors' prices and has the ability to price discriminate between the two markets. The CWB makes most sales f.o.b. at the port of export and in U.S. dollars, but importers' demands are based on the landed price in domestic currency, i.e., on a cost, insurance and freight rate (c.i.f.) basis.[6] Thus, demand is affected by exchange rates and ocean freight rates. Moreover, EU importers must pay an import duty when importing wheat from outside the EU and some countries received EEP subsidies from the U.S. government until 1995.[7]

With those additions, the objective function of the CWB is to maximize producers' surplus by choosing f.o.b. prices to each market subject to a quantity constraint (Q_H) – the amount shipped cannot exceed the harvested quantity of wheat:

$$\max_{p_H^1, p_H^2} R = \left(p_H^1 - c_H^1\right) D_H^1\left(p_H^{1\$}e^1, p_L^{1\$}e^1; \delta^1\right) + \left(p_H^2 - c_H^2\right) D_H^2\left(p_H^{2\$}e^2, p_L^{2\$}e^2; \delta^2\right) +$$
$$\lambda\left(Q_H - D_H^1\left(p_H^{1\$}e^1, p_L^{1\$}e^1; \delta^1\right) - D_H^2\left(p_H^{2\$}e^2, p_L^{2\$}e^2; \delta^2\right)\right),$$

where:

$$D_H^1\left(p_H^{1\$}e^1, p_L^{1\$}e^1; \delta^1\right) = \frac{Y^1}{2k_H k_d^1}\left(\left(K_1\right)^2 - \left(\frac{\left(p_H^{1\$}e^1 k_L - p_L^{1\$}e^1 k_H\right)}{g^1(w)(k_H - k_L)}\right)^2\right), \tag{7}$$

$$D_H^2\left(p_H^{2\$}e^2, p_L^{2\$}e^2; \delta^2\right) = \frac{Y^2}{2k_H k_d^2}\left(\left(K_2\right)^2 - \left(\frac{\left(p_H^{2\$}e^2 k_L - p_L^{2\$}e^2 k_H\right)}{g^2(w)(k_H - k_L)}\right)^2\right), \tag{8}$$

$$p_H^{m\$} = p_H^m + T^m + \frac{D^m}{e^m}, \tag{9}$$

$$p_L^{m\$} = p_L + T^m + \frac{D^m}{e^m} - EEP^m, \; m = 1,2, \tag{10}$$

c_H^m is the cost of marketing wheat to market *m*, T^m is the ocean freight rate to market *m* (in U.S. dollars), e^m is the exchange rate for market *m* (domestic currency per U.S. dollar), D^m is the duty in market m (in domestic currency), EEP^m is the EEP bonus offered to market *m* (in U.S. dollars), δ^m is a vector of other exogenous variables for market *m* (i.e., $Y^m, K_m, k_H, k_L, k_d^m, g^m(w)$), and λ is the Lagrange multiplier.

Note that equations 7 and 8 correspond to equations 4 and 5 except that prices entering the demands are the landed prices in the destination's currency, $p_H^{m\$}e^m$ and $p_L^{m\$}e^m$, instead of the f.o.b. prices in the exporter's currency, p_H^m and p_L^m. The prices $p_H^{m\$}, p_L^{m\$}$ are the landed price in U.S. dollars. Separate data on freight rates for Canada and the U.S. are not available. Consequently, it is assumed that the ocean freight rates are the same from Canada and the

[6] Prices quoted cost-insurance-freight include all costs to ship wheat to the destination port, including ocean freight rates and insurance.

[7] The EEP bonuses are export subsidies that are allocated to specific countries chosen by the U.S. government. U.S. exporting firms agree on sales price and potential EEP bonuses with importers. U.S. firms then submit EEP bids to the Commodity Credit Corporation (CCC) of the USDA. The exporter with the lowest bid receives the subsidy. Therefore, importers do not directly receive the subsidy from the CCC, but receive it through U.S. exporting firms.

United States to any given country. This assumption is reasonable because bread wheat is produced in adjacent areas in Canada and the United States and exported through ports located close to each other on the East Coast and the West Coast. The first-order conditions are:

$$p_H^1 = c_H^1 + \lambda - D_H^1\left(p_H^{1\$}e^1, p_L^{1\$}e^1;\delta^1\right)\frac{\partial p_H^1}{\partial D_H^1(\cdot)}, \tag{11}$$

$$p_H^2 = c_H^2 + \lambda - D_H^2\left(p_H^{2\$}e^2, p_L^{2\$}e^2;\delta^2\right)\frac{\partial p_H^2}{\partial D_H^2(\cdot)}, \tag{12}$$

$$Q_H = D_H^1\left(p_H^{1\$}e^1, p_L^{1\$}e^1;\delta^1\right) + D_H^2\left(p_H^{2\$}e^2, p_L^{2\$}e^2;\delta^2\right).^{8} \tag{13}$$

Equations 11 and 12 are the supply relationships and their reduced-form versions are used to develop an empirical test of price discrimination.

4.3 An Empirical Test of Price Discrimination

A common approach used to test for price discrimination in international trade is the Pricing-to-Market (PTM) approach (Krugman, 1987). The PTM model is based on the idea that an exporter with the ability to price discriminate can exploit changes in demand elasticities caused by movements in exchange rates whereas a perfectly competitive firm cannot. In fact, not only exchange rates are instruments of price discrimination. Other variables such as transportation costs and government policy instruments (taxes, import quotas, import duties, export subsidies, etc.) can also be used to price discriminate because they rotate or shift the demand curve perceived by the exporter. However, the PTM method has been used primarily to test for exchange rate induced price discrimination. The basic PTM model (Knetter, 1989) consists of a fixed-effects model, where price at time *t* to destination *i* is expressed as a function of time, country effects, and exchange rate for destination *i* at time *t*.

It is important to note that most empirical applications use this approach to test for price discrimination using highly aggregated data and assuming homogeneous goods. However, significant country effects, which indicate different markups to different destinations, may in fact capture different qualities of product shipped to the destinations. Arnade and Pick (1999) alleviate this problem by controlling for the different quality imported by using per capita income as a proxy variable. The rationale is that countries with higher per capita income import higher quality wheat.

Taking the difference in price or the log of the price ratio (Borenstein, 1989) facilitates estimation as it eliminates common variables to the two price equations. More importantly, as emphasized by Arnade and Pick (1999), it eliminates marginal cost when it can be assumed that the marginal cost to two destinations is the same. The approach of Borenstein (1989) and Arnade and Pick (1999) can be used to develop a test of price discrimination in wheat exports while accounting for the presence of vertically differentiated goods. This can be achieved by obtaining reduced-form versions of equations 11 and 12 and taking their difference (Lavoie, 2001). The resulting expression consists of the difference in price between high-quality wheat sold to two markets:

[8] It is assumed that the quantity constraint is binding and that the quantity imported of high-quality wheat is positive in both markets. A binding quantity constraint indicates that all wheat available is marketed and not thrown away. By replacing the f.o.b. price in equation 3 by the landed price in domestic currency and by manipulating that equation, it can be observed that high-quality wheat is imported in any market for high enough values of the marginal processing cost (expressed in U.S. dollars), transportation cost, and the import duty (expressed in U.S. dollars). Small enough EEP bonus to a given country will also ensure that a positive quantity of high-quality wheat is purchased.

$$p_H^{1*} - p_H^{2*} = \beta_1 + \beta_2\left(c_H^1 - c_H^2\right) + \beta_3\left(\frac{k_H - k_L}{k_L}\right)\left(T^1 - T^2\right) + \beta_4\left(\frac{k_H - k_L}{k_L}\right)\left(\frac{D^1}{e^1} - \frac{D^2}{e^2}\right) \\ - \beta_5\frac{k_H}{k_L}\left(EEP^1 - EEP^2\right) + \beta_6\left(\frac{k_H - k_L}{k}\right)\left(\frac{K_1 g^1(w)}{e^1} - \frac{K_2 g^2(w)}{e^2}\right). \tag{14}$$

This equation forms the basis of a test of price discrimination when a state-trader markets a higher-quality product relative to its competitors. If the state-trader can price discriminate, relative movements in ocean freight rates (T^m), duties (D^m), EEP subsidies (EEP^m), exchange rates (e^m), marginal processing cost ($g^m(w)$), and quality standard (K_m), will explain changes in the relative prices. However, if the state-trader does not have market power, the only factor that will affect the difference in f.o.b. price will be a difference in the cost of marketing wheat to these two destinations $\left(c_H^1 - c_H^2\right)$.

Interestingly, a measure of relative quality (k_H/k_L) or relative quality difference [$(k_H-k_L)/k_L$] between wheat *H* and *L* multiplies each term. When $k_H=k_L$ equation 14 reduces to:

$$p_H^1 - p_H^2 = \frac{1}{3}\left(c_H^1 - c_H^2\right) - \frac{2}{3}\left(EEP^1 - EEP^2\right). \tag{15}$$

In this case, wheat from the United States and Canada are identical and the CWB cannot exploit changes in local processing costs, shipping costs or import duties because of competition from the low-quality sellers. Rather, the price difference between market 1 and market 2 is due only to differences in marketing costs to the CWB and differences in the EEP bonuses in the two markets. In other words, when $k_H=k_L$ and the CWB price discriminates, Canadian price differences adjust to EEP bonus differences. A price discriminating CWB can react strategically to a trade policy established by another country, such as the U.S. EEP subsidy, by allocating wheat to EEP- and non-EEP markets to maximize producer surplus. Thus, both wheat quality differences and U.S. government trade policy allow the CWB to price discriminate.

When $k_H>k_L$, wheat is heterogeneous. The greater the quality difference, the more the CWB can exploit cost differences (processing costs, shipping costs, and import duties) between the two importing markets, i.e., the more the CWB can price discriminate. The third, fourth, and sixth components of equation 14 have the same effect on the difference in price of wheat *H* in the two markets. That is, as the difference in freight rates, import duties, or processing cost increases between the two markets, the f.o.b. price difference increases.[9] An increase in the ocean freight rate, import duties or processing cost in market 1 increases market 1's demand for wheat *H* (see equations 7 and 8). To understand this effect, replace the f.o.b. prices in equation 3 by the landed prices and manipulate the equation such that wheat *H* is purchased if:

$$\frac{\left(p_H^m + T^m\right)e^m + D^m + g^m(w)k^m}{\left(p_L + T^m\right)e^m - EEP^m + g^m(w)k^m} < \frac{k_H}{k_L}. \tag{16}$$

The left-hand side represents the cost ratio of milling with wheat *H* versus *L*. An increase in ocean freight rate, import duty or processing cost will cause this ratio to decrease. In other words, an increase in freight rate, duty or processing cost makes wheat *H* cheaper relative to wheat *L*, a result akin to the theorem developed by Alchian and

[9] The last term of equation 14 can be interpreted as a measure of difference in processing cost between two countries, where higher end-product quality raises processing costs. This term contains elements impacting the cost savings in processing high-quality wheat relative to low-quality wheat. Recall that $g^m(w)/e^m$ is the marginal processing cost of wheat in market *m* expressed in U.S. dollars. Using the high-quality wheat reduces processing costs and this effect is more important the greater are marginal processing costs, $g^m(w)$.

Allen (1964).[10] Because wheat *H* becomes cheaper relative to wheat *L*, more millers in market 1 will prefer wheat *H*, therefore shifting the demand for wheat *H* in that market to the right. The quantity sold in market 1 increases, whereas the quantity sold in market 2 decreases by the same amount because the quantity of wheat *H* is fixed (figure 1). Thus, an increase in duty, freight rates, or processing cost to market 1 raises the high-quality price to both markets, but relatively more in market 1.

[*Insert figure 1 here*]

The importance of the Alchian-Allen effect is determined by the factor

$$\left(\frac{k_H - k_L}{k_L}\right),$$

i.e., by the extent of product differentiation. Because processing costs, transportation costs, and duties are levied per unit of volume, as these per-unit charges increase, it enhances the desirability of importing the high-quality wheat because less is needed to produce a given finished product. The importance of vertical differentiation in price discrimination is magnified by all costs that are denominated in volume units.

The fourth term examines the effect of EEP on the price difference between two markets. Through a similar effect as a difference in freight rate and import duty differences, an increase in EEP bonus in market 2 results in an increase in the price difference between market 1 and 2. This confirms the general perception that the CWB has to decrease prices in the markets receiving the EEP subsidy in order to make sales. As with import duties, transportation costs and processing cost, the effect of the EEP bonus difference is amplified by the relative quality of the products.

This empirical model isolates the different bases for price discrimination. First, product differentiation enables the CWB to take advantage of a number of price discrimination instruments through an Alchian-Allen effect. This effect is possible because of cross-country differences in variables that create a price wedge between the Canadian f.o.b. price and the landed price (transportation cost, exchange rate, import duties) and in domestic factors such as processing costs. Second, U.S. policy instruments, such as the EEP bonus, provide another basis for price discrimination. Thus, expression 14 is appealing because it isolates the bases for price discrimination and demonstrates that the ability of the CWB to exploit cost differences in pricing depends on the extent of the differentiation between Canadian and U.S. wheat.

4.4 CWB Data

The CWB provided a confidential data set consisting of monthly average price and total quantity of Canada Western Red Spring (CWRS) wheat of grade 1 and 2 sold, as recorded in CWB contracts. Those two grades are primarily used for milling and bread making. The data were obtained for four markets: Japan, United Kingdom, and two aggregate markets consisting of sales of CWRS wheat to all other countries. These two markets are the Rest-of-the-World west coast (ROW-WC) and the Rest-of-the-World east coast (ROW-EC). ROW-WC comprises all sales shipped via the west coast of Canada, except to Japan. ROW-EC comprises all sales shipped via the east coast of Canada, except to the United Kingdom.

The data are disaggregated by port of origin (west coast or east coast) and protein content. Wheat is sold and shipped at 0.5 percent protein level increments from 11.5 percent to 14.5 percent protein. The data are recorded monthly according to the date the sales contract is signed and all prices are expressed in U.S. dollar/metric ton and on an f.o.b. basis at the port of export. A sample observation would consist, for example, of the January 1985 sales price and quantity for No. 1 CWRS wheat with 12.5 percent protein for exports to Japan via west coast ports. The period covered is from November 1982 to July 1994. Because each market buys at least one type of Canadian wheat in each

[10] The Alchian-Allen theorem states that adding the same per unit charge, such as transportation cost, to the price of two substitute goods will decrease the relative price of the higher priced (higher quality) good, thus increasing its relative consumption.

month, there are a total of 1405 observations (159 observations for Japan, 213 observations for the United Kingdom, 498 observations for ROW-WC, and 535 observations for ROW-EC).

It is instructive to examine the data graphically to obtain a first impression of the possible presence of price discrimination. For this purpose, the price differences for CWRS wheat of the same grade and protein level sold to two markets during the same month and originating from the same port are plotted in figures 2 and 3. Figure 2 plots the prices to Japan minus the prices to ROW-WC. Most points on this figure are above zero indicating that the CWB prices to Japan are higher than prices to ROW-WC. Note that this graph ignores many data points where, in a given month, wheat of a given grade and protein content is sold to ROW-WC, but not to Japan.

[*Insert figure 2 here*]

It is interesting to observe that the pattern of the price difference between Japan and ROW-WC is related to the size of the U.S. EEP bonus of HRS wheat offered to some countries in the ROW-WC, but not to Japan.[11] The EEP bonus is an export subsidy offered by the U.S. government to certain countries. When selling to those countries receiving the EEP subsidy, the CWB must reduce its price in order to make the sale. Therefore, in months where the EEP subsidy is large, as in 1988 and 1991, the price difference between Japan and ROW-WC is also large, indicating a large degree of price differentiation between Japan and ROW-WC. However, when the EEP bonuses are small, such as in 1989, there is less price differentiation between Japan and ROW-WC as indicated by the small price differences.

Figure 3 shows the price differences for CWB sales to the United Kingdom relative to sales to ROW-EC. Both sets of prices are expressed on an east coast f.o.b. basis. Some of the markets that are part of ROW-EC have received the EEP subsidy since its introduction in 1985. The price differences between the United Kingdom and ROW-EC are not as high as the Japan – ROW-WC price differences. In fact, some data points indicate that ROW-EC prices are higher than prices to the United Kingdom.

[*Insert figure 3 here*]

These figures display the ability of the CWB to charge different prices for the same wheat quality. Yet, it is also clear that these differences are by no means constant, may not be representative of the complete data set, and are not evidence that those prices maximize producer surplus. The empirical model will provide further insights regarding the ability of the CWB to price discriminate in a manner consistent with producer surplus maximization and regarding the contribution of variables that would explain price differences under perfect competition.

5. Empirical Model

The implementation of the empirical framework described in equation 14 requires some modifications. The model must be expanded to take into account the presence of different grades within both the high- and low-quality wheat exports. Both Canada and the United States export multiple grades and protein levels of bread wheat. Therefore, variables accounting for the difference in wheat grade and protein level must be added. Moreover, intrinsic quality varies with the grade and protein content. Thus, there cannot be only one quality difference factor multiplying the difference in variables such as transportation cost, duties, and EEP bonus. A solution is to multiply each term of the difference by the intrinsic quality difference variable corresponding to the destination. For example, if wheat of quality k_H^1 and wheat of quality k_L^1 are shipped to market 1, and wheat of quality k_H^2 and wheat of quality k_L^2 are shipped to market 2, then the variables reflecting the difference in transportation cost can be expressed as

$$\left(\frac{k_H^1 - k_L^1}{k_L^1} T^1 - \frac{k_H^2 - k_L^2}{k_L^2} T^2 \right).$$

[11] Note that the EEP bonus is expressed in dollar value on the vertical axis to the right of this graph.

When marketing multiple qualities, the single-desk seller faces a quantity constraint for each wheat quality. Different quantity constraints imply that the shadow value of the quantity constraint does not cancel when subtracting the equilibrium price of wheat to destination 2 from the price of wheat to destination 1. The difference in the shadow values can be proxied by the remaining supply of the grade and protein level in question during the month under consideration. With an increase in the constrained quantity, the shadow value of the constraint decreases, reflecting a lower scarcity rent.

Proxies for the variables in equation 14 for which data are unavailable must also be found. A proxy or index of wheat quality k_H and k_L must be constructed. Because protein quantity and quality were emphasized as being some of the most important factors in bread-making, I use a measure of loaf volume as a measure of wheat quality.[12] Given the aggregation of the available data, this quality measure is constructed by interacting the measure of loaf volume with the average protein quality of the corresponding harvest and with the specific content of wheat exported in a manner similar to Stiegert and Blanc (1997).

As in Arnade and Pick (1999), the quality standard (K_m) in each market is proxied with real GDP per capita in each country. The marginal processing cost of wheat can be approximated with labor cost. Note that exchange rates appear only in multiplicative form in the third and fifth term of equation 14 to convert duties and domestic processing costs to U.S. dollars. To follow the PTM literature, an exchange rate index is added separately to equation 14. $XRATE^i$ is an index of the exchange rate in market i where the observation for January 1990 is 100. The difference in this variable for two export markets accounts for the separate effect of a change in the exchange rate difference on the price difference. An appreciation of market 1's exchange rate, i.e., a decrease in e^1, results in an increase in the price difference between market 1 and 2. Equation 14 can be further modified as follows to obtain a regression equation:

$$\begin{aligned} p_{Hi}^1 - p_{Hj}^2 = {} & \beta_0 + \beta_1\left(S_{Hi} - S_{Hj}\right) + \beta_2\left(c_H^1 - c_H^2\right) + \beta_3\left(grade^1 - grade^2\right) \\ & + \beta_4\left(protein^1 - protein^2\right) + \beta_5\left(\left(\frac{k_H^1 - k_L^1}{k_L^1}\right)T^1 - \left(\frac{k_H^2 - k_L^2}{k_L^2}\right)T^2\right) \\ & + \beta_6\left(\left(\frac{k_H^1 - k_L^1}{k_L^1}\right)\frac{D^1}{e^1} - \left(\frac{k_H^2 - k_L^2}{k_L^2}\right)\frac{D^2}{e^2}\right) + \beta_7\left(\frac{k_H^1}{k_L^1}EEP^1 - \frac{k_H^2}{k_L^2}EEP^2\right) \\ & + \beta_8\left(\left(\frac{k_H^1 - k_L^1}{k_L^1}\right)\frac{wage^1}{e^1}GDP^1 - \left(\frac{k_H^2 - k_L^2}{k_L^2}\right)\frac{wage^2}{e^2}GDP^2\right) \\ & + \beta_9\left(XRATE^1 - XRATE^2\right) + \varepsilon. \end{aligned} \tag{17}$$

The variables are defined in table 1 with the data source in parenthesis.

[*Insert table 1 here*]

6. Results

Three sets of estimation based on equation 17 were examined to determine the impact of different specifications. The conceptual model predicts that intrinsic wheat quality (loaf volume) enters the model multiplicatively. The model specified in equation 17 was tested against a specification where the relative difference in loaf volume between Canadian and U.S. wheat to two destinations was added additively as opposed to multiplicatively in the model. Two non-nested tests, the F-test and the J-test, were performed on these two specifications to determine which is preferred. Results of both tests suggest that there is explanatory power to be gained by combining the two models. In other words, a hybrid model

[12] Loaf volume is the volume of a loaf of bread baked from wheat samples taken as wheat is loaded into cargoes. Other protein quality measures were used (wet gluten content and farinograph absorption) and similar results were obtained.

where intrinsic wheat quality enters the model both multiplicatively and additively is preferred. The resulting hybrid model corresponds to:

$$\begin{aligned} DPRICE = {} & INTERCEPT + \beta_1 DCOST + \beta_2 DGRADE + \beta_3 DPROTEIN + \beta_4 DPROT2 \\ & + \beta_5 DAVSUP + \beta_6 DWAGE + \beta_7 DWAGEL + \beta_8 DXRATE + \beta_9 DOCEAN \\ & + \beta_{10} DOCEANL + \beta_{11} DDUTY + \beta_{12} DDUTYL + \beta_{13} DEEP + \beta_{14} DEEPL \\ & + \beta_{15} LOAF1 + \beta_{16} LOAF2 + \varepsilon. \end{aligned}$$

Appendix I provides a detailed description of the variables used in this estimation, their expected sign, and their units of measurement. Notice that the manufacturing wage appears in the variables DWAGE and DWAGEL and is not interacted with the quality standard (proxied with real GDP) because this variable performed slightly better without the interaction.

Ordinary Least Squares regressions were run for each of six market pairs: Japan and United Kingdom, Japan and ROW-EC, Japan and ROW-WC, United Kingdom and ROW-EC, United Kingdom and ROW-WC, and ROW-EC and ROW-WC. The dependent variable is the f.o.b. price difference of wheat of the same or different quality (grade and protein content) between two markets. The data is of a panel nature where the cross-sections represent the different combinations of grade and protein content that can be shipped to two markets. For each pair of markets there is a possibility of 196 cross-sections because the data obtained from the CWB are for two grades of CWRS wheat and seven protein levels. Thus, there are 14x14 possible combinations. For example, if, during the time period of interest (1982-1994), the CWB sold only CWRS No. 1 13.5 percent protein, No. 1 14.5 percent protein, and No. 2 13.5 percent protein to Japan, and No. 1 13.5 percent protein and No. 1 14.5 percent protein to the United Kingdom, the panel data for the Japan-United Kingdom market pair has 6 cross-sections. The time series for the different cross-sections for a given market pair are stacked for the estimation.

Each variable in the model consists of the difference between two variables corresponding to the two markets under consideration. For variables interacted with the relative loaf volume difference between Canadian and U.S. wheat exports, the variable's coefficient represents the effect of a one-unit increase in the difference of the quality-adjusted variable on the price difference between the two markets. For example, suppose the price difference between Japan and the United Kingdom is examined. The coefficient for DOCEANL represents the effect of an increase of \$1/metric ton in the quality-adjusted freight rate difference between Japan and the United Kingdom on the price difference between these two markets. Alternatively, the coefficient could be interpreted as either the effect of a \$1/metric ton increase in the quality-adjusted freight rate to Japan or the effect a \$1/metric ton decrease in the quality-adjusted freight rate to the United Kingdom. Both effects should cause an increase in the price difference between these two markets. For ease of exposition, the "quality-adjusted" terminology will not be used, but will be implied by the variable name ending with "L" such as DOCEANL.

The estimation results are presented in table 2. The variables can be divided and examined in three categories: those that explain the price difference in perfect competition only (DCOST, DGRADE, DPROTEIN, and DAVSUP), those that create an Alchian-Allen effect (DWAGE, DWAGEL, DOCEAN, DOCEANL, DDUTY, and DDUTYL), the EEP subsidy (DEEP, DEEPL), DXRATE, and the loaf volume measure. The fit of the models, as illustrated by the adjusted R^2 for the different market pairs, varies between 0.40 and 0.48. This relatively low performance is not surprising given the panel nature of the data.

[*Insert table 2 here*]

DCOST represents the difference in transportation cost from a mid-prairie point to the port of export and takes the value of zero when wheat is exported from the same port. The coefficient on this variable has the expected sign for all relevant market pairs, except ROW-EC/ROW-WC. A change in internal shipping and handling cost has the greatest impact on the price difference between Japan and the United Kingdom. The coefficient indicates that on average during 1982-1994, a \$1/metric ton increase in the difference in shipping cost to the west coast relative to the east coast of Canada resulted in \$3.39/metric ton increase in the f.o.b. price difference between Japan and the United

Kingdom. A $1/metric ton increase in the shipping cost to the west coast would cause the CWB to decrease the quantity exported to west coast markets, such as Japan and ROW-WC, and increase the quantity exported to east coast markets, such as United Kingdom and ROW-EC. This reallocation would occur until the net marginal revenue (marginal revenue minus cost of shipping) to all markets are equal. Therefore, an increase in the shipping and handling cost to the west coast would result in an increase in the marginal revenue and price to Japan and in a decrease in the marginal revenue and price to the United Kingdom. While the difference in marginal revenue between Japan and the United Kingdom should equal one to compensate for the one-unit change in DCOST, the impact on the price difference may be smaller, equal, or greater than one depending on the elasticities of demand. Therefore, it is not surprising to find a coefficient for DCOST that is greater than one.

The coefficient for DGRADE can be interpreted as the value to each market in the pair of increasing the grade from No. 2 to No. 1. The estimated value of an increase in grade ranges between $6.94/metric ton for Japan/ROW-WC pair to $17.42/metric ton for the Japan/United Kingdom pair.[13]

The coefficients for DPROTEIN are significant, at least at the ten percent level, and have the right sign. The sign on the coefficient on DPROT2 indicates that the protein price schedule is concave as expected. Finally, the other variable that can account for price differences under perfect competition is DAVSUP. This variable represents the difference in available supply of wheat of different grades in each month, and it is zero when the wheat shipped to different destinations is the same grade in a given month. It is a proxy for the shadow value of the quantity constraint. An increase in the available supply should cause a decrease in wheat price because it is associated with a decrease in the scarcity rent. The coefficient for this variable has the expected negative sign, except for United Kingdom – ROW-EC and ROW-EC – ROW-WC.

In many instances, coefficients on both the variable interacted with loaf volume and its counterpart, not interacted with the quality measure, are significant. This suggests that including the two variables adds explanatory power and does not cause multicollinearity.

Given the interaction of most other variables with the loaf volume, the marginal effect of a variable on the price difference must be computed using the coefficients in table 2 and average values for the variable during the time period under study. Table 3 computes those marginal effects for the variable associated with one of the markets comprising the price difference.

[*Insert table 3 here*]

An increase in the ocean freight rate to market 1 has the expected effect, to increase the price difference between the two markets for three market pairs (Japan – United Kingdom, Japan – ROW-EC, and United Kingdom – ROW-EC). The coefficient indicates that a $1/metric ton increase in the ocean freight rate to Japan resulted on average during the period of study in a $1.61/metric ton increase in the price difference between Japan and the United Kingdom, everything else held constant. Increases in ocean freight rates create an Alchian-Allen effect in those market pairs and makes the high-quality wheat more valuable to markets that value quality. Japan and the United Kingdom are well known for their high-standards and requirements of high-quality, which may justify the importance of this variable for those markets.

An increase in the import duty for the United Kingdom had the expected effect for all market pairs concerned. The impact of an increase in the duty on the price difference is small. For example, an increase in $1/metric ton in the duty resulted in an increase in the price to the United Kingdom and therefore a decrease in the price difference between Japan and the United Kingdom by $0.04/metric ton on average for 1982-1994.

The impact of an increase in the EEP subsidy to market 2 is positive as expected and varies between $0.04/metric ton for the price difference between the United Kingdom and ROW-WC and $0.21/metric ton Japan – ROW-WC market pair. An increase in the subsidy is only partly matched by the CWB. In fact, those results indicate that the CWB decreased its price less than the European Community in EEP markets, based on the results reported by Haley (1992).

Finally, an increase in the relative loaf volume difference between Canadian and U.S. wheat shipped to market 1 (LOAF1) caused an increase in the price difference for Japan – United Kingdom, United Kingdom – ROW-EC, and

[13] This specification assumes that the value of an increase in grade is the same for both markets.

United Kingdom – ROW-WC. The coefficient indicates that an increase in the loaf volume of Canadian wheat relative to U.S. wheat by one unit (essentially, doubling the loaf volume of Canadian wheat) results in an increase in the price difference between Japan and the United Kingdom by $32.29/metric ton.

According to the F-statistics, the model of perfect competition is rejected for all market pairs, indicating that the imperfect competition variables add significant explanatory power to the model. However, the variables that should affect the price differences only under imperfect competition do not have the expected sign for all market pairs. Thus, the results of the F tests do not imply that the CWB price discriminates in a way that maximizes static producer surplus.

7. Conclusion

State-trading enterprises (STEs) such as the Canadian Wheat Board (CWB) and Australian Wheat Board (AWB) are controversial organizations. Recent challenges to those organizations have prompted a number of studies to examine the benefits and costs of the CWB and the AWB. Proponents of those STEs, such as Kraft, Furtan and Tyrchnewicz (1996), have compared the price obtained by the CWB with the price of U.S. competitors. The observed price premium was attributed to the ability of the CWB to exert market power through price discrimination. However, surveys of importers (Mercier, 1993 and Stephens and Rowan, 1996) have shown that Canadian and Australian wheat are often viewed by importers as being of higher quality than U.S. wheat. Thus, the price premium observed could be partly or even fully due to a quality difference. Opponents of the CWB (Carter, Loyns, and Berwald (CLB), 1998 and NDWC, 2000) have argued that the CWB over-delivers on protein content. The over-delivery is viewed as an inefficiency of the CWB (CLB, 1998) or a form of predatory pricing (NDWC, 2000). These arguments demonstrate the importance of considering the heterogeneity of wheat when evaluating the performance of organizations such as the CWB and the AWB.

This study has developed a conceptual and empirical model to examine price discrimination in the wheat industry when trade is characterized by the presence of state-traders, and wheat can be described as a vertically differentiated intermediate good. Previous approaches in the trade and in new empirical industrial organization literature have focused primarily on horizontally differentiated consumer goods. This study modified the vertical differentiation model of Mussa and Rosen (1978) to the realities of wheat imports. The model isolates the bases of price discrimination and demonstrates that the CWB's ability to exploit cost differences in pricing depends on the extent of the differentiation between Canadian and U.S. wheat.

The conceptual model was implemented using confidential price data provided by the CWB. Inspection of the data indicates that the CWB charges different f.o.b. prices to different countries for wheat of the same grade and protein content. Moreover, results from the empirical model indicate that the price difference between any two markets is not completely explained by elements of perfect competition, such as a difference in grade or protein content, a difference in handling and shipping cost to different Canadian ports, or a difference in scarcity rent.

However, the evidence is mixed regarding the ability of the CWB to utilize all the instruments available to price discriminate. This result suggests that the practices of the CWB are not necessarily consistent with static producer surplus maximization – the assumed objective of the CWB in this study. Thus, those results do not provide conclusive evidence regarding the ability of the CWB to obtain a price premium over comparable quality of U.S. wheat that is due to its market power.

The results of the empirical model must be interpreted with caution. Many of the variables used to explain the effects of imperfect competition are only proxies for the correct variables, which are either unmeasurable or for which the available measures suffer from aggregation problems. Moreover, the CWB may be pursuing a dynamic pricing strategy and may be reluctant to adjust prices in response to every movement in variables such as ocean freight rates and import duties to avoid alienating customers. Thus, the results may simply indicate that the CWB's pricing strategy is more complex and dynamic than the prescription for static optimization derived in this study.

References

Alchian, A.A., and W.R. Allen. 1964. *University Economics*. Belmont, Calif.: Wadsworth.

Arnade, C. and D. Pick. 1999. Alternative Approach to Measuring Oligopoly Power: A Wheat Market Example. *Applied Economics Letters* 6:195-197.

Booz, A. and H. 1995. Milling Wheat Project: Consultant's Report to the Australian Grains Council. Canberra.

Borenstein, S. 1985. Price Discrimination in Free-Entry Markets. *Rand Journal of Economics* 16:380-397.

Borenstein, S. 1989. Hubs and High Fares: Dominance and Market Power in the U.S. Airline Industry. *Rand Journal of Economics* 20:344-365.

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

Canadian Wheat Board. 2001. *CWB's Vision, Mission, and Goals*. Online: http://www.cwb.ca

Carter, C.A. and R.M.A. Loyns. 1996. *The Economics of Single Desk Selling of Western Canadian Grain*. Edmonton, AB, Canada: Alberta Agriculture, Food and Rural Development.

Carter, C.A, R.M.A. Loyns and Berwald. 1998. Domestic Costs of Statutory Marketing Authorities: the Case of the Canadian Wheat Board. *American Journal of Agricultural Economics* 80:313-324.

Cooper, J.C., E. Giraud-Héraud, and V. Réquillart. 1995. Economic Impacts of Isoglucose Deregulation on the European Sweetener Market. *European Review of Agricultural Economics* 22:425-445.

Dahl, B.L. and W.W. Wilson. Department of Agricultural Economics, North Dakota State University. 1997. *Factors Affecting the Supply of High Quality Spring Wheats: Comparisons Between the United States and Canada.* Agricultural Economics Report No. 374.

Haley, S.L. 1992. The US Export Enhancement Program: Prospects under the Food, Agriculture, Conservation, and Trade Act of 1990. *Food Policy* 17:129-140.

Katz, M.L. 1984. Price Discrimination and Monopolistic Competition. *Econometrica* 53:1453-1471.

Knetter, M.M. 1989. Price Discrimination by U.S. and German Exporters. *American Economic Review* 79:198-210.

Kraft, D.F., W.H. Furtan and E.W. Tyrchniewicz. Canadian Wheat Board., Winnipeg, Canada. 1996. Performance Evaluation of the Canadian Wheat Board.

Krugman, P. 1987. Pricing to Market When the Exchange Rate Changes. In *Real-Financial Linkages Among Open Economies.* Ed. Arndt, S.W. and J.D. Richardson. Cambridge:MIT Press.

Lavoie, N. 2001. Price Discrimination in the Context of Vertical Differentiation: An Application to Canadian Wheat Exports. Ph.D. diss., University of California, Davis.

North Dakota Wheat Commission. 2000. *N.D. Wheat Commission to File Section 301 Against Canada*. Online: http://www.ndwheat.com/in/news/news_detail.asp?ID=115

Mercier, S.A. U.S. Department of Agriculture, Economic Research Service. 1993. *The Role of Quality in Wheat Import Decision making*. Agriculture Economic Report No. 670.

Miner, W.M. 2001. An Overview of the Issues and Positions of the Major Countries in the WTO Negotiations. *Estey Center Journal of International Law and Trade Policy* 2:10-34.

Mussa, M. and S. Rosen. 1978. Monopoly and Product Quality. *Journal of Economic Theory* 18:301-317.

Piggott, R.R., 1992. Some Old Truths Revisited. *Australian Journal of Agricultural Economics* 36:117-140.

Ryan, T.J. 1984. Marketing Australia's Wheat Crop: The Way Ahead. *Review of Marketing and Agricultural Economics* 62:107-121.

Schmitz, A., R. Gray, T. Schmitz, and G. Storey. 1997. *The CWB and Barley Marketing: Price Pooling and Single-Desk Selling*.

Stephens, D.G. and F.T. Rowan. Research Program, Western Grain Marketing Panel, The Exchange Consulting Group. 1996. Procurement Systems of International Buyers and Changing Marketing Systems and Policies of International Competitors. Winnipeg, MB.

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

Thursby, M.C. 1988. Strategic Models, Market Structure, and State Trading: An Application to Agriculture. In *Trade Policy Issues and Empirical Analysis.* Ed. Baldwin, E. NBER Conference Report Series, Chicago and London: University of Chicago Press.

Tweed, A.R. 1993. Breadmaking Technology. In *Grains and Oilseeds: Handling, Marketing, Processing. Fourth Edition.* Canadian International Grains Institute: Winnipeg, Canada.

Williams, P. 1997. Variety Developments and Quality Control of Wheat in Canada. Paper presented at the International Japanese Conference on Near-Infrared Reflectance. Online: http://www.cgc.ca/Cdngrain/VarietyDev/variety1-e.htm

Appendix I. Description of the variables used in the estimations.

Variable	Expected Sign	Calculation[1]	Units
DPRICE		$p_{Hi}^{1} - p_{Hj}^{2}$	Real 1990 U.S. dollars/metric ton
DCOST	+	$c_{H}^{1} - c_{H}^{2}$	Real 1990 U.S. dollars/metric ton
DGRADE	-	$grade^{1} - grade^{2}$	No units
DPROTEIN	+	$protein^{1} - protein^{2}$	Percent of protein
DPROT2	-	$\left(protein^{1} - protein^{2}\right)^{2}$	Percent of protein squared
DAVSUP	-	$S_{Hi} - S_{Hj}$	Millions of metric tons
LOAF1	+	$\frac{\left(LOAF_{Hi}^{1} - LOAF_{Lr}^{1}\right)}{LOAF_{Lr}^{1}}$	No units
LOAF2	-	$\frac{\left(LOAF_{Hj}^{2} - LOAF_{Ls}^{2}\right)}{LOAF_{Ls}^{2}}$	No units
DWAGE	+	$\frac{wage^{1}}{e^{1}} - \frac{wage^{2}}{e^{2}}$	Thousands of real 1990 U.S. dollars per month.
DWAGEL		$LOAF1 \cdot \frac{wage^{1}}{e^{1}} - LOAF2 \cdot \frac{wage^{2}}{e^{2}}$	Thousands of real 1990 U.S. dollars per month.
DXRATE	-	$XRATE^{1} - XRATE^{2}$	No units. Real 1990 domestic currency to U.S. dollar exchange rate measured in index form (January 1990 = 1)
DOCEANL	+	$LOAF1 \cdot OCEAN^{1} - LOAF2 \cdot OCEAN^{2}$	Real 1990 U.S. dollars/metric ton
DOCEAN	+	$OCEAN^{1} - OCEAN^{2}$	Real 1990 U.S. dollars/metric ton
DDUTYL	+	$LOAF1 \cdot \frac{DUTY^{1}}{e^{1}} - LOAF2 \cdot \frac{DUTY^{2}}{e^{2}}$	Real 1990 U.S. dollars/metric ton
DDUTY	+	$\frac{DUTY^{1}}{e^{1}} - \frac{DUTY^{2}}{e^{2}}$	Real 1990 U.S. dollars/metric ton
DEEPL	-	$\frac{LOAF_{Hi}^{1}}{LOAF_{Lr}^{1}} EEP^{1} - \frac{LOAF_{Hj}^{2}}{LOAF_{Ls}^{2}} EEP^{2}$	Real 1990 U.S. dollars/metric ton
DEEP	-	$EEP^{1} - EEP^{2}$	Real 1990 U.S. dollars/metric ton

[1] The superscript 1 indicates the market representing the first element of the difference and the superscript 2, the market associated with the second element of the difference. $LOAF_{Hi}^{1}$ is the loaf volume (in cm^3) of CWRS wheat of type *i* shipped to market 1, $LOAF_{Hj}^{2}$ is the loaf volume of CWRS wheat of type *j* shipped to market 2, $LOAF_{Lr}^{1}$ is the loaf volume of DNS wheat of type *r* to market 1, and $LOAF_{Ls}^{2}$ is the loaf volume of DNS wheat of type *s* to market 2. The type refers to the grade and protein content.

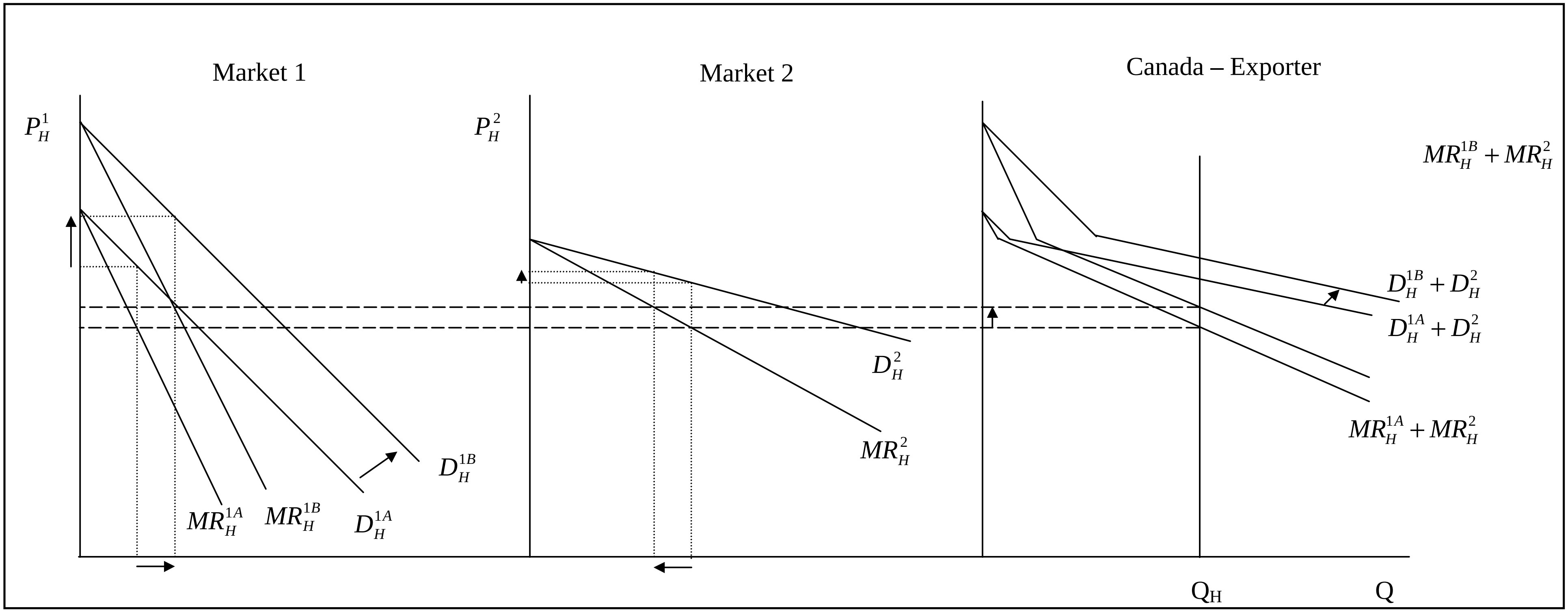

Figure 1. Effect of an increase in the freight rate, duty, or processing cost in market 1.

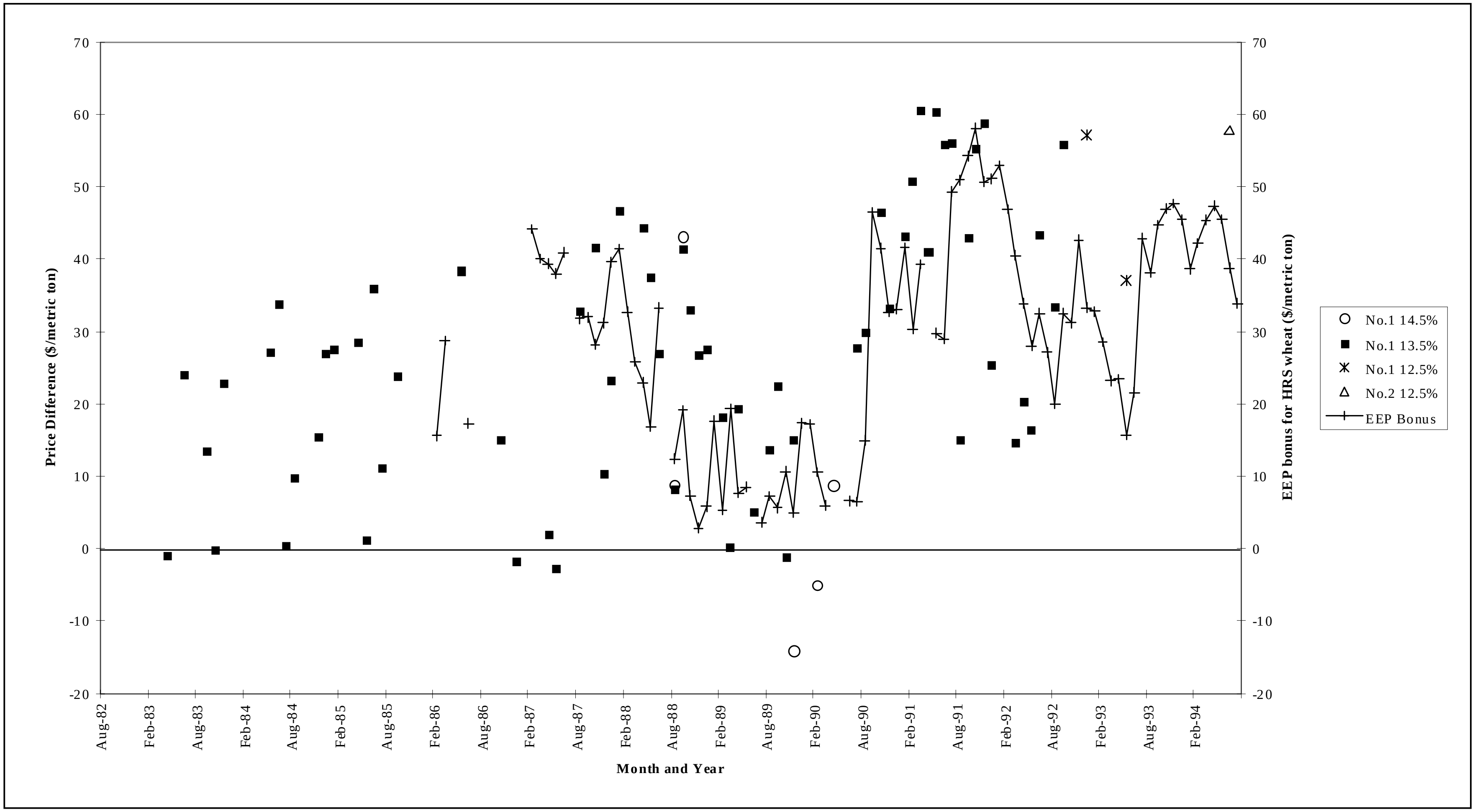

Figure 2. Price difference between Japan and ROW-WC for CWRS wheat (f.o.b. west coast) in relation to the EEP subsidy for HRS wheat.

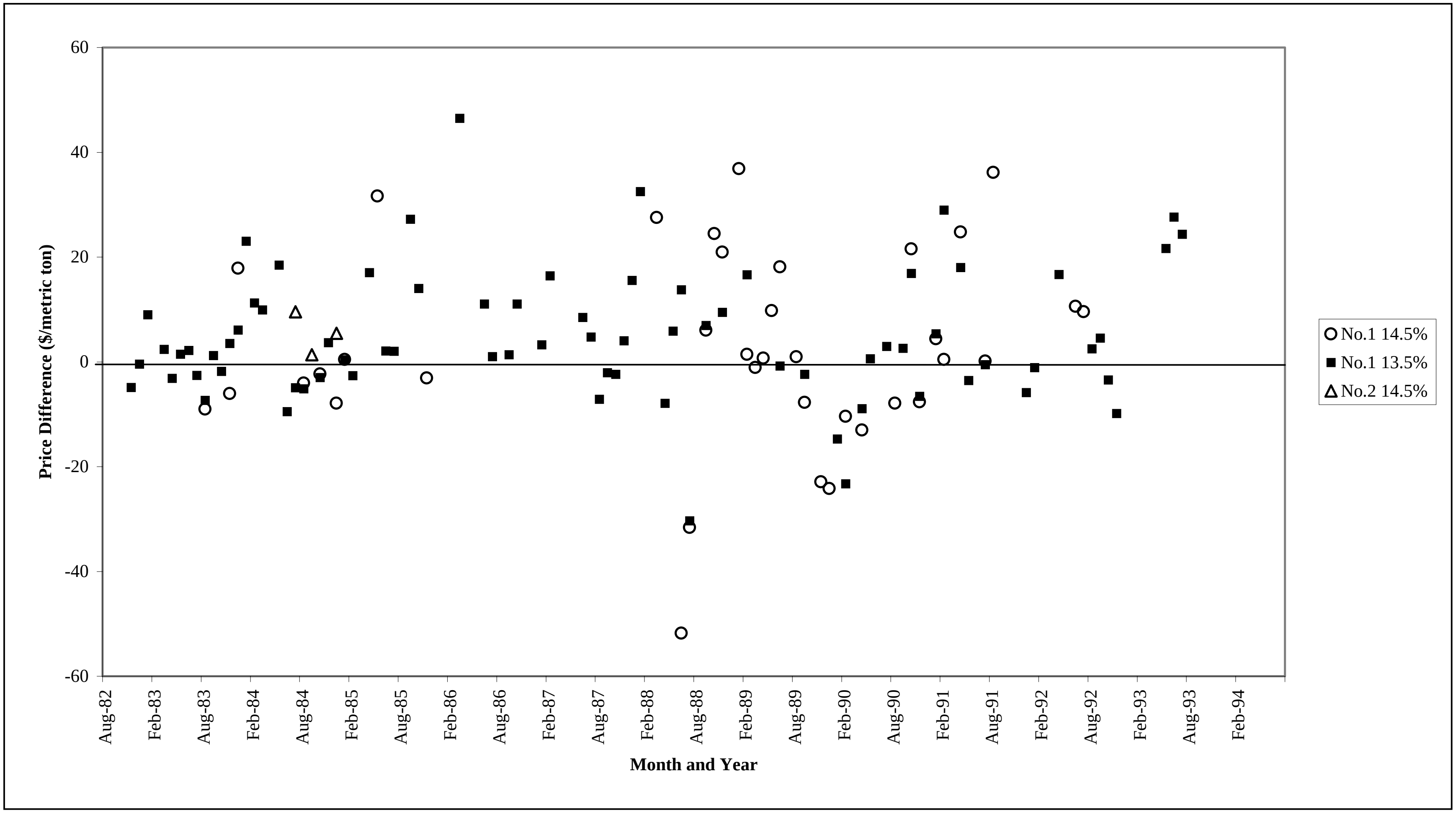

Figure 3. Price difference between the United Kingdom and ROW-EC for CWRS wheat (f.o.b. east coast).

Table 1. Definition of the variables included in equation 17[1].

Variable	Definition
p_{Hi}^{1}	Price of type *i* (grade and protein content) of the high-quality wheat sold to market 1 (Source: CWB).
p_{Hj}^{2}	Price of type *j* (grade and protein content) of the high-quality wheat sold to market 2 (Source: CWB).
S_{Hi}	Available supply of Canadian wheat of type *i* (Source: Canada Grains Council, *Statistical Handbook*).
S_{Hj}	Available supply of Canadian wheat of type *j* (Source: Canada Grains Council, *Statistical Handbook*).
c_{H}^{m}	Handling cost of bringing wheat from a Canadian mid-prairie point (Sintaluta, SK) to the port of embarkment of wheat for market *m*, *m=1, 2.* (Source: Canadian Grain Commission, *Canadian Grain Exports*).
$grade^{m}$	Grade of Canadian wheat sold to market *m*, $grade^{m}$ = 1, 2 (Source: CWB).
$protein^{m}$	Protein content of Canadian wheat sold to market *m*, $protein^{m}$ = 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5 (Source: CWB).
T^{m}	Ocean freight rates to market *m* (Source: International Wheat Council, *World Grain Statistics*).
D^{m}	EU import duty (Source: Home-Grown Cereals Authority, *Cereal Statistics*).
e^{m}	Exchange Rate of market *m* (Source: United Nations, *Statistical Yearbook*).
EEP^{m}	U.S. Export Enhancement Program bonus for wheat in market *m* (Source: CWB).
$wage^{m}$	Real manufacturing earnings in market *m* (Source: United Nations, *Statistical Yearbook*).
GDP^{m}	Real GDP in market *m* (Source: United Nations, *Statistical Yearbook*).
k_{H}^{m}	Loaf volume of Canadian wheat sold to market *m* (Source: Canadian Grain Commission, *Quality of Western Canadian Wheat*).
k_{L}^{m}	Loaf volume of U.S. wheat sold to market *m* (Source: USDA GIPSA grain inspection data and U.S. Wheat Associates, *Crop Quality Report*).
$XRATE^{m}$	Index of exchange rate in market *m*.

[1] A detailed description of the construction of those variables can be found in Lavoie (2001).

Table 2. Estimation results for the hybrid model

	Japan-United Kingdom	Japan-ROW-EC	Japan-ROW-WC	United Kingdom-ROW-EC	United Kingdom-ROW-WC	ROW-EC-ROW-WC
INTERCEPT	44.2252	4.2223	39.6747	29.0166	-28.4108	-2.0925
	(2.36)	(0.27)	(5.39)	(7.17)	(-1.41)	(-0.28)
DCOST	3.3919	0.8540			1.7363	-0.0593
	(4.71)	(1.34)			(2.01)	(-0.17)
DGRADE	17.4199	15.8909	6.9474	17.0298	8.0768	9.7014
	(3.63)	(12.01)	(4.50)	(13.63)	(5.43)	(13.67)
DPROTEIN	6.8472	5.0240	11.8438	3.6424	7.5869	8.6388
	(3.32)	(2.72)	(4.76)	(1.89)	(3.80)	(9.98)
DPROT2	-1.1685	1.1453	-1.4872	-0.6209	-0.2582	-0.5988
	(-0.69)	(1.51)	(-1.97)	(-1.09)	(-0.45)	(-2.82)
DAVSUP	-1.4565	-0.0175	-0.0563	-0.2665	0.0838	0.2093
	(-2.12)	(-0.11)	(-0.33)	(-1.81)	(0.48)	(2.41)
DWAGE	23.6313	14.0693	-5.0977	-26.4841	-19.7930	1.3524
	(4.29)	(6.51)	(-1.50)	(-3.52)	(-3.24)	(0.29)
DWAGEL	49.5415	101.9157	163.5932	118.7273	-202.0345	220.7887
	(1.53)	(4.13)	(5.65)	(2.84)	(-4.06)	(7.15)
DXRATE	40.9612	0.0048	-6.7763	-0.0051	-7.8466	0.0005
	(4.03)	(4.83)	(-4.50)	(-3.92)	(-5.35)	(0.74)
DOCEAN	1.5015	1.9510	-0.0180	0.2836	-0.7213	-0.4514
	(3.75)	(6.89)	(-0.06)	(0.75)	(-2.58)	(-3.75)
DOCEANL	3.4952	-9.4862	-10.5171	-8.7286	2.2815	-10.8349
	(0.94)	(-3.90)	(-2.92)	(-4.36)	(0.83)	(-10.32)
DDUTY	0.0157			0.0177	0.0881	
	(0.76)			(1.02)	(3.58)	
DDUTYL	0.5737			-0.1000	0.2421	
	(4.42)			(-0.69)	(1.45)	
DEEP		-1.6483	-0.8918	-1.3749	-1.5653	
		(-3.81)	(-1.83)	(-3.44)	(-3.67)	
DEEPL		1.5623	0.7042	1.2106	1.5579	
		(3.52)	(1.39)	(2.93)	(3.46)	
LOAF1	-166.5352	-46.8286	-167.8290	-0.9977	209.8366	101.0899
	(-1.62)	(-0.58)	(-1.50)	(-0.02)	(3.88)	(4.30)
LOAF2	194.1134	-118.3000	-247.3312	-150.8240	5.3303	-283.7315
	(3.97)	(-3.02)	(-2.59)	(-4.02)	(0.07)	(-10.35)
Adjusted R^2	0.4485	0.4841	0.4182	0.4035	0.3979	0.4083
N	240	597	560	824	730	2128

Note: Numbers in parentheses are t-statistics.

Table 3. Effect of an increase of one unit in a variable on the price difference for each market pair based on results for the hybrid model.

Variable	Calculation	Japan–United Kingdom	Japan–ROW-EC	Japan–ROW-WC	United Kingdom–ROW-EC	United Kingdom–ROW-WC	ROW-EC–ROW-WC
DCOST	β_1	3.3919	0.8540			1.7363	-0.0593
DGRADE	β_2	-17.4199	-15.8909	-6.9474	-17.0298	-8.0768	-9.7014
DPROTEIN	$\beta_3 + 2\beta_4 DPROTEIN$	7.7967	5.5305	10.5690	2.8059	7.1399	8.3858
DAVSUP	β_5	-1.4565	-0.0175	-0.0563	-0.2665	0.0838	0.2093
WAGE1	$\beta_6 + \beta_7 LOAF1$	25.2304	15.9892	-2.5272	-23.3306	-23.5439	-2.4204
DXRATE	β_8	40.9612	0.0048	-6.7763	-0.0051	-7.8466	0.0005
OCEAN1	$\beta_9 + \beta_{10} LOAF1$	1.6143	1.7723	-0.1833	0.0518	-0.6789	-0.2663
DUTY1	$\beta_{11} + \beta_{12} LOAF1$				0.0150	0.0926	
DUTY2	$-\beta_{11} - \beta_{12} LOAF2$	-0.0367					
EEP2	$-\beta_{13} - \beta_{14} LF2$		0.0940	0.2069	0.1617	0.0424	
LOAF1	$\beta_7 WAGE1 + \beta_9 OCEAN1 + \beta_{11} DUTY1 + \beta_{14}$	32.2920	-42.9815	-31.3683	42.6886	13.8061	-10.4804
LOAF2	$-\beta_7 WAGE2 - \beta_9 OCEAN2 - \beta_{11} DUTY2 - \beta_{13} EEP2 + \beta_{15}$	6.8037	-22.3296	-24.1330	-68.2108	-60.5806	-44.5215

Note: $LF2 = \dfrac{LOAF_{Hj}^2}{LOAF_{Ls}^2}$

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