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Estimation of Source- and Quality-Differentiated Import Demand Under Aggregate Import Quota: An Application to Japan's Wheat

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Introduction

Since a seminal work by Armington (1969), estimating source-differentiated import demand has become a useful tool in applied international trade research. Trade policy evaluation and simulation require reliable estimates of the responsiveness of import demand to international price changes. Unfortunately, for certain commodities, reliable estimation of import demand is a particularly arduous task given the pervasive presence of quantitative restrictions in international trade. Import quotas, for example, have been implemented in many countries for a variety of products. In spite of its apparent importance to trade policy analysis, surprisingly little attention has been paid to investigate the impact of an import quota on the estimation of import demand. One exception is the work by Bertola and Faini (1991). They applied the theory of rationing of Neary and Roberts (1980) to investigate the impact of an import quota on the import demand for commodities under quota and non-quota regimes. Similar to the work on demand and production theory under rationing, their results allow one to predict non-rationed import behavior from observations on a market under import rationing. Such results are particularly useful for investigating the effect of complete trade liberalization. To further research on this important, but neglected topic, we consider a different case where an aggregate import quota is applied to a seemingly homogenous product differentiated by country of origin.

The objective of the present study is to provide a theoretical and empirical methodology for the estimation of source-differentiated import demand under import quota. The model is developed specifically in the context of the Japanese wheat import but applicable generally. The wheat import demand differentiated by class and country of origin is derived from a restricted profit function for the Japanese grain importers. Wheat is chosen because many importing countries rely on quota licenses for all wheat imports (USDA 1997). Japan is selected because Japan is one of the most important international wheat markets. As a result of Japan's conversion of import quotas to tariff-rate quotas, and agreement to reduce its state-trading markup on wheat in 1995, wheat exporters' access to the Japanese market is expected to increase. It is therefore of interest for policymakers and exporters to know the potential effect of this increased market access on the Japanese wheat import demand.

The rest of the paper is organized as follows. Section II presents a brief review of previous estimation of the Japanese wheat import demand and summarizes some important features of the Japanese wheat importing process. Section III characterizes the importers' behavior under import quota in terms of the restricted profit function. Section IV discusses the specification of flexible functional form models and derives a system of import demand functions under import quota. Finally, empirical results are presented. Section VI is a summary with conclusions.

Background

Several previous studies estimated the Japanese wheat import demand differentiated by class and country of origin. Japan mainly imports five classes of wheat from three countries, including U.S. hard red winter (HRW), U.S. hard red spring (HRS), U.S. white, Canada's winter red spring number 1 (CWRS1), and Australia soft. On the basis of end use, hard wheat (HRW, HRS, and CWRS1) is used to produce cake and bread, while soft wheat (U.S. white and Australia soft) is used to produce noodles. Honma and Heady (1984) have used the Armington model to analyze Japanese wheat import demand by class and country of origin. Mao, Koo, Suomala, and Sakurai (1997) have applied a multiple output–multiple input translog cost function for the Japanese flour industry to analyze Japanese import demand for wheat. Others have used a complete demand system such as the almost ideal demand system, the translog expenditure, the Rotterdam model, and Barten's system-wide approach to analyze the Japanese import demand for wheat classes (Henning 1986, Agriculture Canada 1987, Lee, Koo, and Krause 1994, Wilson 1994, Schmitz and Wahl 1998). None of these studies have explicitly considered the impact of an import quota on the estimation of the Japanese wheat import demand. Such an omission may lead to biased estimates of the responsiveness of import demand to price changes and thus limits the usefulness of these studies.

To model import quotas, it is important to know how the wheat import quotas are implemented in Japan. Unfortunately, like most quantitative restrictions, the administration of the Japanese wheat import quota lacks transparency. Its quota allocation guidelines are not clear. Various designated authorities are involved in Japan's wheat importing process before wheat is purchased by the end users. The Japanese Food Agency (JFA) determines the domestic wheat purchase plan for wheat each year in August or September in consultation with the representatives of flour millers and the domestic wheat producers. After the domestic purchase plan is set, the JFA will hold semi-annual meetings with the flour millers, bakers, the noodle industry, and private trading companies to finalize its wheat import plan. The quantity of wheat imported is set to clear the domestic market at the administrated resale prices (OECD 1987). The wheat trading companies, licensed by the JFA, import wheat by class at world prices under aggregate import quota and tender the wheat to the JFA at their purchase price plus a mark-up reflecting ocean freight, insurance, carrying costs, etc., to deliver the wheat to Japan. The JFA then resells the imported wheat to domestic flour and bran millers at higher administered resale prices (Alston, Carter, and Jarvis 1990). The mills reflect their demand at the administrated resale price. The Japanese government has been using the system of import quotas and high resale prices to protect and subsidize its domestic wheat and rice production.

Existing literature are often focused on the role of the JFA (Alston, Carter, and Jarvis 1990, OECD 1987, Love 1991). Little attention has been paid to differentiate among the roles played by various authorities – between the authority to determine the aggregate quantity of imports and those licensed to procure imports. Given the fact that the actual wheat imports are carried out by the private grain importers, it is useful to consider the role of private grain importers when modeling the Japanese wheat import demand. The issue becomes even more interesting as the private grain importers are likely to play a more active role in the Japanese wheat trade in the era of a more free trade. In the following sections, the grain importers are assumed to determine where and what to import wheat through the pure middleman profit maximization solution, subject to an aggregate level of wheat import set by the JFA. The results show that modeling the behavior of the private grain importers provides a unique approach to the study of the source-differentiated import demand under import quota.

The Model

The JFA sets the aggregate level of wheat imports at Q and distributes Q to each grain importer such that $Q = \sum_{i}^{n} q_i$, where q_i is the import quota allocated to the i^{th} importer. The i^{th} grain importer faces a quota constraint such that $\sum_{j}^{m} \sum_{k}^{s} q_{ijk} \le q_i$. The i^{th} grain importer buys the j^{th} class of wheat (q_{ijk}) at the world price (w_{jk}), and sells to the JFA at the purchase price (p_{jk}), where j and k stand for the j^{th} wheat class and k^{th} origin, respectively. Consequently the price received by the importer is the markup $\left(p_{jk} - w_{jk}\right)$. The importer is assumed to have no market power over the JFA and wheat exporters. The i^{th} importer also faces competitive non-wheat input market and employs an aggregate of non-wheat inputs (i.e., labor, transportation, building, and land etc.) at unregulated aggregate price *(r)*.

The i^{th} importer solves the problem

$$\underset{(q_{ijk})}{Max}\left[\sum_{j}^{m}\sum_{k}^{s}\left(p_{jk} - w_{jk}\right)q_{ijk} - C_i\left(r; q_i\right) : \sum_{j}^{m}\sum_{k}^{s} q_{ijk} = q_i\right] \tag{1}$$

where $C_i(\cdot)$ is a well-behaved cost function.

The first order conditions of the i^{th} importer at an optimum are:

$$p_{jk} - w_{jk} - \frac{\partial C_i\left(r; q_i\right)}{\partial q_{ijk}} - w_i = 0 \;\; ; \;\; \forall\, j = 1,2\ldots\ldots, m \text{ and } k = 1,2,\ldots\ldots, s \tag{2}$$

$$q_i - \sum_j^m \sum_k^s q_{ijk} = 0 \qquad (3)$$

where w_i is the shadow price of an import quota, q_i. Equation (2) states that, at the optimum, the markup adjusted for a shadow price of the import quota equals marginal cost. It is worth noting that, in the absence of import quota, the importers choose the optimal import plan by equating the markup and marginal cost.

Equations (2) and (3) together provide a complete base for testing the impact of the import quota on the import demand and supply. The import quota has a significant impact if the hypothesis $w_i = 0$ is rejected. Application of the equations (2) and (3) will likely require the use of firm-level panel data. Such data are unavailable in the case of Japan. Because most applications of import demand utilize aggregate data, it is important to consider conditions needed for consistent aggregation across firms. First, a quasi-homothetic cost function is required (Chambers 1988). As such, we assume that the importer's cost function takes the Gorman polar form $C_i(r, q_i) = c(r)h(q_i) + g(r)$. Second, non-jointness in production is needed in multiple-output case (Hall 1973). This implies that the marginal cost of importing j^{th} wheat class from k^{th} country of origin is unaffected by importing level of wheat class j'^{th} wheat class from k'^{th} country of origin.

The remaining aggregation condition concerns the shadow price of import quota. To derive the aggregate shadow price, one way is to use a quantity-share weighted average of the individual shadow prices such that

$$w = \sum_i^n \sum_j^m \sum_k^s \frac{q_{ijk}}{Q} w_i \qquad (4)$$

Equation (4) implies that consistent aggregation is assured to hold only if each firm's share is identical across wheat classes or if all firms have the same w. While the former is unlikely to hold exactly, the latter holds *ex post* if the quota market is competitive. Optimizing behavior compels that *ex post* firm's shadow prices of import quota are identical.

Suppose that the above conditions for consistent aggregation are met. The aggregate analog of the optimality conditions (2) - (3) may be rewritten as

$$p_{jk} - w_{jk} - \frac{\partial C(r;Q)}{\partial Q} - w = 0 \quad \forall\, j = 1,2\ldots\ldots, m \text{ and } k = 1,2,\ldots\ldots, s \qquad (5)$$

$$Q - \sum_{j}^{m} \sum_{k}^{s} q_{jk} = 0 \qquad (6)$$

where w is the shadow price of an aggregate import quota and $C(r;Q)$ is the industry cost function for the grain importers.

Equation (5) implies

$$p_{jk} - w_{jk} = p_{j'k'} - w_{j'k'} \qquad (7)$$

Equation (6) indicates that, given that the consistent aggregation exists, importers allocate their imports between different wheat classes so that the markup is the same for all types of wheat. In other words, to determine their optimal imports by class and country of origin, the importers respond to the changes of relative markups rather than price per se.

Solving equations (5) and (6) give the following supply and demand system for imported wheat

$$q^*_{jk} = q^*_{jk}(p - w, Q) \quad \forall\, j = 1,2\ldots\ldots, m \text{ and } k = 1,2,\ldots\ldots, s \qquad (8)$$

where $p-w$ is a vector of markups by class of wheat and country of origin. Two important observations can be made in light of equation (8). First, aggregate import quotas appears directly in the import demand function. If a system of import demand is estimated without the relevant aggregate import quota, the estimated markup coefficients will be biased and drawing valid inferences about the estimated markup coefficients becomes impossible - the textbook consequences for omitting relevant variables. The direction of the bias induced on markup responsiveness estimates by the presence of import quota depends on the structure of co-variances between the markups and omitted variable (Greene 1993, p. 246). Second, the import demand function is independent of unregulated aggregate price of non-wheat inputs and the shadow price of the import quota. This feature is empirically attractive as information on the prices and usage of non-wheat inputs. As well the shadow price of import quotas is often hard to obtain.

Given equation (8), the quota-constrained gross profit function can be defined as

$$p\,(p-w,Q) = \underset{q_{jk}}{Max}\left[\sum_{j}^{m}\sum_{k}^{s}(p_{jk}-w_{jk})q_{jk}^{*}(p-w,Q) : \sum_{j}^{m}\sum_{k}^{s} q_{jk} = Q\right] \qquad (9)$$

The word 'gross' signals that this measure of the profit includes all non-wheat input cost as well as the quota rent. The properties we assume for this function are standard: non-decreasing in markups and quota, symmetric, convex, and linearly homogenous in markups, continuous and twice differentiable. The first derivative of the profit function with respect to markup, known as Hotelling Lemma (McFadden 1978), produces both supply and demand functions for wheat

$$\frac{\partial p}{\partial(p_{jk}-w_{jk})} = \frac{\partial p}{\partial p_{jk}} = -\frac{\partial p}{\partial w_{jk}} = q_{jk}^{*} \qquad (10)$$

Empirical Specification

Duality theory has been used extensively in recent literature to analyze multiple output production relationships. To approximate multiple output profit function, three locally flexible functional forms (translog, generalized Leontief, and normalized quadratic) are often used. It is well known that convexity is not a general property of those three locally flexible function forms. In our preliminary analysis, all three forms produced positively sloped demand functions for some wheat classes. Such results indicate that the estimated equations were inconsistent with the convex property of the profit function. To ensure the estimation of a theoretically consistent profit function, convexity needs to be imposed on estimation. For that purpose, the normalized quadratic specification (Lau 1976) was chosen over the translog and generalized Leontief. With the normalized quadratic specification, one can impose convexity in markups on parameter estimates of the restricted profit function and continue to identify separate elasticities between individual pairs of inputs (Diewert and Wales 1987, Dupont 1991). A multi-output quadratic profit function normalized at the z*th* markup series can be written as

$$\begin{aligned} \frac{p(M,Q)}{M_z} = {} & a_0 + \sum_{j}^{m-1}\sum_{k}^{s-1} a_{jk}\frac{M_{jk}}{M_z} + \frac{1}{2}\sum_{j}^{m-1}\sum_{k}^{s-1}\sum_{j'}^{m-1}\sum_{k'}^{s-1} b_{jk,j'k'}\frac{M_{jk}}{M_z}\frac{M_{j'k'}}{M_z} \\ & + b_Q Q + \frac{1}{2} b_{QQ} Q^2 + \sum_{j}^{m-1}\sum_{k}^{s-1} l_{ijk,Q}\frac{M_{jk}}{M_z} Q \end{aligned} \qquad (11)$$

where M_{jk} is the markup of importing the j^{th} wheat class from the k^{th} country of origin $(p_{jk} - w_{jk}), M_{jk}$ is the markup of importing the j'^{th} wheat class from the k'^{th} country of origin $(p_{jk} - w_{jk})$, and a, b and l are parameters. This function maintains linear homogeneity of the profit function and is self-dual. Define the matrix $\boldsymbol{B}$ with element $b_{jk,j'k'}$. Symmetry in cross markup terms is obtained by defining the matrix $\boldsymbol{B}$ to be symmetric. The restricted profit function satisfies convexity in markups whenever the $\boldsymbol{B}$ matrix is positive semi-definite. Lopez (1985) notes that the normalized quadratic profit function imposes quasi-homotheticity. This means that the marginal rate of substitution between input pairs are independent of the level of outputs. This restriction represents no limitation of this study as non-wheat inputs do not enter equation (9).

Using equation (10), the demand and supply equations for the j^{th} class of wheat from k^{th} country of origin can be derived as

$$q_{jk} = a_{jk} + \sum_{j'}^{m-1}\sum_{k'}^{s-1} b_{jk,j'k'} \frac{M_{j'k'}}{M_z} + l_{jk,Q} Q \text{ ; } \forall\ jk \neq z \text{ and } j'k' \neq z \qquad (12)$$

$$q_z = a_0 + b_Q Q + \frac{1}{2} b_{QQ} Q^2 \qquad (13)$$

It is interesting to note that, given estimates of the system of equation (12) and (13), all parameters of the profit function can be retrieved. As insufficient observations often prevent researchers from estimating the profit function itself, this feature is attractive. It is particularly so when the shadow prices of quota are of interest.

The parameters of the demand and supply equations for the z^{th} wheat class (*numeraires*) can be derived from the quota restriction (5)

$$q_z = \left(-\sum_{j}^{m-1}\sum_{k}^{s-1} a_{jk}\right) + \left(-\sum_{j}^{m-1}\sum_{k}^{s-1}\sum_{j'}^{m-1}\sum_{k'}^{s-1} b_{jk,j'k'} \frac{M_{j'k'}}{M_z}\right) + \left(1 - \sum_{j}^{m-1}\sum_{k}^{s-1} l_{jk,Q}\right) Q \qquad (14)$$

such that

$$\sum_{j}^{m}\sum_{k}^{s} a_{jk} = 0, \sum_{j}^{m}\sum_{k}^{s} l_{jk} = 1, \text{ and } \sum_{j}^{m}\sum_{k}^{s} b_{jk,j'k'} = 0 \qquad (15)$$

To measure responsiveness of each wheat class demand with respect to change in the markup, the markup elasticities for wheat class are derived as

$$h^{m}_{jk,j'k'} = \frac{b_{j,j'k'k}}{q_{j'k'}} \frac{M_{j'k'}}{M_z}; \forall\, jk \neq z \text{ and } j'k' \neq z \tag{16}$$

$$h^{m}_{z,j'k'} = -\sum_{j'}^{m-1}\sum_{k'}^{s-1} \frac{b_{z,j'k'}}{q_z} \frac{M_{j'k'}}{M_z}; \forall\, j'k' \neq z \text{ and } jk = z \tag{17}$$

The price elasticities of import demand are related to the markup elasticities in the following way

$$h^{d}_{jk,j'k'} = -\frac{w_{j'k'}}{M_{j'k'}} h^{m}_{jk,j'k'} \tag{18}$$

To evaluate how demand for each wheat class respond to changes in the level of aggregate quota, the quota elasticities are calculated as

$$e_{jk,Q} = \frac{l_{jk,Q} Q}{q_{jk}} \tag{19}$$

The gross shadow price of the aggregate import quota can be calculated as

$$\frac{\partial p(M,Q)}{\partial Q} = b_Q M_z + b_{QQ} Q M_z + \sum_{j}^{m-1}\sum_{k}^{s-1} l_{jk,Q} M_{jk} \tag{20}$$

The term ‘gross’ is used because p is the gross profit inclusive of all non-wheat inputs. The calculated gross shadow price of import quota will have two components, the shadow price itself plus the marginal cost of importers (excluding wheat purchase cost). As such the gross shadow price of import quota should not be interpreted as the rental rate. To compute the rental rate, one would need information on the marginal cost of grain importers.

Data and Estimation Results

The empirical estimation of equation (11), (12) and (13) requires information on wheat sales, wheat export prices (FOB), and JFA's wheat purchase prices (CIF Japan) by class and country of origin. Five classes of wheat, including U.S. hard red winter (HRW), U.S. hard red spring (HRS), U.S. white, Canada's winter red spring number 1 (CWRS1), and Australia soft, are considered. Other classes are not included in the analysis for they account for less than 2% of Japan's wheat imports. The annual import data for the period from 1971/72-1995/96 were available from the World Wheat Statistics of the International Grain Council (IGC), the Canadian Wheat Board Annual Statistics, and USDA.

The FOB prices, C&F prices, and ocean freight rates for HRS, HRW, WHITE, ASW, and CWRS1 are available from the IGC. It should be noted that the FOB prices are "asking" prices and may diverge from competitive values in recent years (Wilson 1994). This is particularly the case of the Canadian export prices. Since actual transaction prices are considered to be "top" trade secrets and are not published, the extent of such divergence is unknown. Goodwin and Smith (1995) indicate that the asking prices likely over state actual transaction prices as the former do not include the discounts often associated with exports. Since HRS, HRW, WHITE, and CWRS1 are imported from the Pacific to Japan, a time series of the FOB prices at Pacific port is used for HRS, HRW, WHITE, and CWRS1. Our discussion with officials actively involved in the grain trade to Japan indicates that these price series are more reliable (compared to the FOB prices at Gulf). As such we conjecture the econometric problems associated with the use of these price series should be minimized. Initially, the markups by class and country of origin is calculated as the difference between the JFA's wheat purchase prices and wheat export prices (FOB) differentiated by class and country of origin minus the associated freight rates. Some of the resulting markups for the early years between 1971/72 and 1979/80 are negative. During that period, only the freight rates quoted for vessel size A (15-20,000 metric ton) were reported by IGC, while, in the later years, only the rates for vessel size B (20-35,000 metric ton) were reported. We suspect that the negative markups are caused by apparently larger freight rates during the period between 1971/72 and 1979/80. To maintain reasonable degree of freedom in estimation, we cannot afford to delete these negative markups. The markups by class and country of origin in this paper is then defined as the difference between the JFA's wheat purchase prices and wheat export prices (FOB) differentiated by class and country of origin. The definition and descriptive statistics of all variables are presented in Table 1.

Instead of estimating the restricted profit function in (11), the system of four demand and supply equations in (12) was estimated. Prior to estimation, error terms are appended to each of the four demand and supply equations. The random terms are assumed to be contemporaneously correlated but serially un-correlated. The system was initially estimated using Zellner's iterative seemingly unrelated regression with symmetry imposed. As monotonicity and convexity are not general properties of the normalized quadratic, resulting parameters are checked for acceptance of monotonicity and convexity in markups. All five estimated demand equations are positive, which are consistent with the monotonicity condition. The presence of negative own markup and positive own price coefficients for some wheat classes indicates that the estimated equations are inconsistent with the convex property of the profit function. As convexity is rejected by the data, it is imposed by a re-parameterization procedure introduced by Wiley, Schmidt, and Bramble

(1973). This parameterization uses the product of a triangular matrix ***D*** and its transpose to replace the ***B*** matrix, i.e. $B = DD^T$, such that

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix} = \begin{bmatrix} d_{11} & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix} \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ 0 & d_{22} & d_{23} & d_{24} \\ 0 & 0 & d_{33} & d_{34} \\ 0 & 0 & 0 & d_{44} \end{bmatrix} \quad (21)$$

The restriction does not destroy the flexibility of the ***B*** because ***D*** contains as many independent parameters as ***B*** does (Diewert and Wales 1987).

Assuming symmetry, the correspondence between the b and d parameters are as follows:

$$\begin{aligned} & b_{11} = d_{11}^2; b_{12} = d_{11}d_{12}; b_{13} = d_{11}d_{13}; b_{14} = d_{11}d_{14}; \\ & b_{22} = d_{12}^2 + d_{22}^2; b_{23} = d_{12}d_{13} + d_{22}d_{23}; b_{24} = d_{12}d_{14} + d_{22}d_{24}; \\ & b_{33} = d_{13}^2 + d_{23}^2 + d_{33}^2; b_{34} = d_{13}d_{14} + d_{23}d_{24} + d_{33}d_{34}; \\ & b_{44} = d_{14}^2 + d_{24}^2 + d_{34}^2 + d_{44}^2 \end{aligned} \quad (22)$$

The re-parameterization requires a nonlinear estimation technique. The system was thus estimated using a generalized Gauss-Newton algorithm as implemented in Shazam 7.0. Symmetric and convexity restrictions were imposed on estimation. The parameter estimates of the demand and supply equations are presented in Table 2. Because the re-parameterization procedure was employed, the estimated parameters of the markups in Table 3 are calculated from equation (22). The standard errors are computed by a Taylor-series expansion of the first order and then applying the standard results for variance and covariance of linear functions of random variables (Goldberger 1964). 12 of 15 markup coefficients and all five quota coefficients were significantly different from zero at the 5% level of significance, which suggest that the model fits data well.

Since the theoretical model is developed acknowledging the import quota, it is important to test whether the import demand for individual wheat class is independent of quota. This requires all quota coefficients to be zero. A likelihood ratio test, conditional on the maintained hypothesis of symmetry, homogeneity, and convexity, rejects this null hypothesis at the 1% level of significance. Consequently, the import quota significantly affects the Japanese wheat import demand differentiated by class and country of origin. Similarly, as the theoretical results crucially depend on the assumption of block non-separability among wheat classes, it is important to verify that the estimated model satisfies this structural property. For the restricted profit function, as in equation (9), block separability requires that the import demand for particular class is independent of other classes. This requires all cross markup coefficients to be zero. A likelihood ratio test, conditional on the maintained hypothesis of symmetry, homogeneity, and convexity, rejects this null hypothesis at the 5% level of significance. As a result, the import demand differentiated by class and country of origin are significantly related.

Table 3 reports estimated markup and quota elasticities at the mean. The own markup elasticities for all wheat classes are positive as expected. Their values are less than one, indicating that the demands for different wheat classes are markup inelastic. In other words, 1% increase in markup of particular wheat class would lead to less than 1% increase in the demand for that wheat class. The quota elasticities are used to examine how the change in the level of aggregate import quota affects the import demand for individual wheat class (Table 4). All estimated quota elasticities are positive. The positive sign indicates that the demand for all wheat classes is likely to increase if there is an increase in the overall level of wheat import quota, holding prices constant. The magnitudes of the quota elasticities for CWRS1, HRW, and White are much larger than those of HRS and ASW. The implication is that the demand for CWRS1, HRW, and White would increase more than the demand for HRS and ASW if the Japanese wheat import quotas were to increase.

Table 4 reports estimated price elasticities of the Japanese wheat import demand. The own price elasticities for all wheat classes are negative as expected. The own price elasticities for HRS, ASW, and WHITE are elastic, while those for CWRS and HRW are inelastic, indicating that Japanese imports of HRS, ASW, and WHITE are more sensitive to their prices than those of CWRS and HRW. The cross price elasticities are used to examine competitive relationships among different wheat classes. A positive sign indicates competitive relations, while a negative sign indicates complementary relations. The results indicate the complementary relationships between CWRS1 and HRS, CWRS1 and White, HRS and ASW, and HRW and White in the Japanese wheat market. The complementary relationships could be due to the blending of different types of wheat by millers (Wilson 1994). Competitive relationships are found between CWRS1 and HRW, CWRS1 and ASW, HRS and HRW, HRW and ASW, and ASW and WHITE.

To compare with previous estimates of price elasticities of Japanese wheat import demand by class and country of origin, some of the recent estimates are reported in Table 5. One observation is that the previous estimates appear to vary widely cross studies. While some variations of the reported elasticities are expected due to different data, different period, different market level as well as different estimation methods, they appear to be 'excessive'. In terms of sign, our estimates are close to that reported by Wilson (1994), though, in terms of magnitudes, our estimates are larger.

To estimate the gross shadow prices of the import quotas, equation (13) needs to be estimated. The estimated equation (13) using OLS is

$$q_z = \underset{(129.6000)}{-1.2655} + \underset{(.1723)^*}{0.3020}Q - \underset{(.0000)}{0.0000}Q^2 \qquad (23)$$

where standard errors are in parentheses and an asterik * indicates significance at the 0.05 level. The estimated gross shadow prices of import quota over the period 1971-1995 are presented in Table 6. The shadow prices net of freight rates are also presented in the third column. However, similar to the problem encountered in the markup calculation earlier, subtracting freight rates from the gross shadow value results in some negative numbers for the period 1971/72-1979/80. It appears that the shadow prices net of freight rates have been increased steadily since late 1980's. The fourth column is the ratio of gross shadow prices over average markups. The ratios suggest that gross shadow prices track average markups well over the period 1971/72-95/96.

Concluding Comments

In this paper, a conceptual model of Japanese wheat import demand is developed for the Japanese private grain importers facing quota licenses. Departing from previous studies, the Japanese wheat import demands are specified in terms of markups for different types of wheat class and the aggregate level of import quota is explicitly incorporated in the model. A quota constrained, normalized quadratic profit function is then specified to derive the unconditional wheat import demand. The quota-constrained wheat import demand system was estimated using the nonlinear seemingly unrelated regression with symmetric and convexity restrictions imposed. The testing results indicated that past evidence cannot be relied upon to predict future wheat import flows unless import quota are explicitly accounted for.

Not surprisingly, our estimates of price elasticities of Japanese wheat import demand differ markedly from previous studies. Estimated own price elasticities suggest that Japanese import demands for HRS, ASW, and WHITE are more sensitive to their prices than those of CWRS and HRW, indicating that changes in wheat prices under the current trade negotiation could affect the market shares of HRS, ASW, and WHITE more than those of CWRS and HRW. Estimated quota elasticities suggest that the demand for CWRS1, HRW, and White would increase more than the demand for HRS and ASW if the Japanese wheat import quotas were to increase. These two results suggest that the market shares for CWRS and HRW are likely to rise due to the increased access to Japanese wheat market. Estimated cross price elasticities indicate the complementary relationships between CWRS1 and HRS, CWRS1 and White, HRS and ASW, and HRW and White, and the competitive relationships between CWRS1 and HRW, CWRS1 and ASW, HRS and HRW, HRW and ASW, and ASW and WHITE.

Since import quotas are widely used around the world, the approach developed may be useful in empirical evaluation of other cases where data permits the estimation of restricted profit functions. The information generated is particularly important in evaluating the effect of reduced trade barriers.

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Table 1. Definition and Descriptive Statistics of Variables, 1971/72-95/96

Variable	Definition	Mean (S.D.)
FOBASW	FOB export price, Australia Soft, US$/ton	149.03 (30.18)
FOBCWRS1	FOB export price, Canada's Winter Red Spring No. 1, US$/ton, 13.5%, Pacific (12.5% after 1994 Feb)	181.64 (33.56)
FOBHRW	FOB export price,US Hard Red Winter No. 2, US $ /ton, 13%, Pacific	147.68 (27.63)
FOBHRS	FOB export price, US Hard Red Spring No. 2, US $ per ton, 14%, Pacific	164.04 (31.65)
FOBWHITE	FOB export price, US White, US $ /ton, Pacific	142.52 (25.29)
CFASW	C&F import price, Australia Soft, US$/ton, as fixed at tenders held by the Food Agency	178.52 (40.35)
CFCWRS1	C&F import price, Canada's Winter Red Spring, US$/ton, 13.5%, as fixed at tenders held by the Food Agency (12.5% after Feb 1994)	210.32 (42.33)
CFHRW	C&F import price, US Hard Red Winter No. 2, US$/ton, 13%, as fixed at tenders held by the Food Agency	191.56 (40.48)
CFHRS	C&F import price, US Hard Red Spring N0. 2, US$/ton, 14%, as fixed at tenders held by the Food Agency	198.00 (41.89)
CFWHITE	C&F import price, US White, US$/ton, as fixed at tenders held by the Food Agency	176.44 (35.11)
FRAUS	Annual Average Freight Rates for heavy grain, US$/ton, from Australia to Japan	19.34 (6.16)
FRPACIFIC	Annual Average Freight Rates for heavy grain, US$/ton, from North Pacific to Japan	19.24 (5.93)
MASW	Markup for Australia Soft, measured as a difference between CF and FOB prices minus freight rate, US$/ton	29.98 (13.98)
MCWRS1	Markup for Canada's Winter Red Spring, measured as a difference between CF and FOB prices, US$/ton	28.68 (12.77)
MHRW	Markup for US Hard Red Winter, measured as a difference between CF and FOB prices, US$/ton	43.88 (19.21)
MHRS	Markup for US Hard Red Spring, measured as a difference between CF and FOB prices, US$/ton	33.96 (17.52)

MWHITE	Markup for US White, measured as a difference between CF and FOB prices, US$/ton	33.92 (16.32)

Table 2. Parameter Estimates of the Demand and Supply Equations, 1971/72-95/96

	The Quantity of				
Variables	CWRS1	HRS	HRW	ASW	WHITE
Constant	-4.2045*	-1.6434	0.7841	-3.9393*	9.0032*
	(1.2361)	(1.2252)	(1.4750)	(2.9824)	(2.7345)
MCWRS1	37.550	81.202*	-56.242*	-133.220*	70.708*
	(33.133)	(34.684)	(33.645)	(40.649)	(29.679)
MHRS	81.202*	455.322*	-290.395*	73.556	-319.694*
	(34.684)	(150.360)	(64.460)	(57.424)	(80.953)
MHRW	-56.242*	-290.395*	186.070*	-18.180	179.243*
	(33.645)	(64.460)	(33.318)	(32.460)	(36.946)
MASW	-133.220*	73.556	-18.180	940.310*	-861.971*
	(40.649)	(57.424)	(32.460)	(377.900)	(367.350)
MWHITE	70.708*	-319.694*	179.243*	-861.971*	931.714*
	(29.679)	(80.953)	(36.946)	(367.350)	(381.530)
Total	0.2470*	0.1416*	0.2420*	0.1670*	0.2024*
Quota	(0.0061)	(0.0110)	(0.0063)	(0.0072)	(0.0082)

Note: standard errors are in parentheses, and an asterik (*) indicates significance at the 0.05 level.

Table 3. Estimated Markup Elasticities and Quota Elasticities at the Sample Mean, 1971/72-95/96

	Markup of					Total Quota
Quantity of	CWRS1	HRS	HRW	ASW	WHITE	
CWRS1	0.0266	0.0653	-0.0645	-0.0906	0.0573	1.0630
HRS	0.0774	0.4934	-0.4487	0.0674	-0.1895	0.8210
HRW	-0.0409	-0.2400	0.2193	-0.0131	0.0747	1.0698
ASW	-0.1205	0.0756	-0.0274	0.8178	-0.7456	0.9189
WHITE	0.0712	-0.3218	0.1804	-0.8676	0.9378	1.0811

Table 4. Estimated Price Elasticities of Japanese Wheat Import Demand at the Sample Mean, 1971/72-95/96

	The World FOB Prices of				
Quantity of	CWRS1	HRS	HRW	ASW	WHITE
CWRS1	-0.1694	-0.3178	0.2177	0.4564	-0.2677
HRS	-0.4937	-2.4005	1.5145	-0.3395	0.8019
HRW	0.2608	1.1675	-0.7401	0.0658	-0.3159
ASW	0.7686	-0.3680	0.0925	-4.1180	3.1548
WHITE	-0.4539	1.5656	-0.6090	4.3693	-3.9683

Table 5. Selected Previous Estimates of Price Elasticities of Japanese Wheat Import Demand at the Sample Mean

	CWRS1	HRS	HRW	ASW	WHITE
Wilson (1994), a translog demand system, FOB prices + freight rates, 1976-88					
CWRS1	0.05	-0.02	0.09	0.13	-0.25
HRS	-0.02	-0.53	0.27	-0.21	0.99
HRW	0.09	0.21	-0.28	0.18	-0.21
ASW	0.19	-0.76	0.25	-0.61	0.92
WHITE	-0.34	0.76	-0.25	0.83	-1.21
Lee et al. (1994), an almost ideal demand system, FOB prices, 1965-90					
CWRS1	-1.51	2.15	-0.93	1.81	-1.47
HRS	3.55	-5.29	0.97	1.16	2.75
HRW	-1.49	0.89	-0.27	0.08	-0.10
ASW	2.80	-2.34	0.09	-3.15	1.65
WHITE	-2.90	1.10	-0.26	1.51	-0.95
Mao et al. (1997) , a translog cost function approach, JFA's resale prices, 1976-93					
CWRS1	-6.1483	4.5799	2.1342	0.5604	-1.0073
HRS	3.9684	-5.8598	1.9124	1.4839	-0.7923
HRW	2.7463	2.8400	-7.8622	-1.9921	2.0226
ASW	0.6654	2.0334	-1.8381	-3.2392	1.1288
WHITE	-0.7643	-0.6938	1.1927	0.7213	-3.2487
Schmitz and Wahl (1998), Barten's system-wide approach, FOB prices, 1970-94					
CWRS1	-0.27	-0.25	0.27	0.13	-0.53
HRS	-0.17	-.49	-0.16	0.38	0.25
HRW	0.19	-0.19	0.25	0.38	-0.97
ASW	0.03	0.34	0.27	-4.85	3.63
WHITE	-0.27	0.30	-0.72	3.61	-2.35

Table 6. Gross Shadow Values of Aggregate Wheat Import Quota in Japan, 1971/72-95/96, $/metric ton

Crop Year	Gross Shadow Prices	Shadow Prices Net of Freight Rates	Ratio of Gross Shadow Prices Over Average Markups
1971/72	8.00	1.17	1.33
1972/73	8.00	-3.81	/
1973/74	4.00	-22.43	/
1974/75	28.00	5.78	1.47
1975/76	23.00	8.53	1.47
1976/77	19.00	4.10	1.56
1977/78	15.00	1.01	1.74
1978/79	10.00	-7.92	/
1979/80	19.00	-12.44	/
1980/81	35.00	3.93	1.17
1981/82	37.00	11.24	1.28
1982/83	36.00	18.67	1.12
1983/84	39.00	20.76	1.21
1984/85	39.00	19.73	1.74
1985/86	27.00	9.51	1.08
1986/87	30.00	12.88	1.17
1987/88	30.00	6.07	0.88
1988/89	40.00	13.88	1.06
1989/90	45.00	17.70	1.20
1990/91	44.00	17.80	1.15
1991/92	45.00	30.74	1.14
1992/93	47.00	34.43	1.10
1993/94	50.00	37.46	0.92
1994/95	64.00	46.91	1.35
1995/96	56.00	40.11	1.27
Average	31.92	12.63	1.18