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# Wheat demand in Japanese flour milling industry: a production theory approach

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## Abstract

A production approach based on the translog cost function is used to analyze import demand for wheat differentiated by class and country of origin in the Japanese wheat flour milling industry. Results indicate that US wheat faces strong competition in the Japanese wheat market, but its multiple classes and end-use characteristics enable the US to preserve the largest market share in Japan. © 2001 Elsevier Science B.V. All rights reserved.

*Keywords:* Import demand; Japan; Wheat; Production theory; Translog cost function

## 1. Introduction

Japan is one of the largest wheat importing countries in the world, accounting for about 6% of world total wheat imports in the early 1990s (International Grains Council, 1989–1994). Japanese wheat imports include both food wheat and feed wheat.<sup>4</sup> The US, Canada, and Australia are suppliers to the Japanese wheat import market, with 57.7, 23.5, and 18.8% of

market share, respectively, in 1998. Japanese domestic production only accounted for about 8% of its total wheat supply in 1998 (USDA PS&D, 1994).

Japanese wheat and wheat flour imports have been controlled by the Japanese Food Agency (JFA).<sup>5</sup> The JFA determines the quotas on wheat imports each year in consultation with private milling companies and wheat trading companies. Each miller prepares a request for quantities of various classes of wheat. The wheat trading companies licensed by the JFA import wheat at world prices and sell the wheat to the JFA (Love and Murningtyas, 1992). The JFA then resells the imported wheat to domestic flour and bran millers at higher prices.

The Japanese government has been using the system of import quotas. It also sets high resale domestic prices to protect and to subsidize its domestic wheat production, which was about 15% of domestic consumption in 1993 (Japanese Ministry of Agricul-

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<sup>4</sup> Food wheat is used to produce various types of food products and feed wheat is used to feed animals.

<sup>5</sup> The JFA also purchases domestic wheat from farmers and sells domestic wheat to millers.

ture Forestry and Fisheries, 1955–1995). Japan agreed to convert quotas to tariff rate-quotas (TRQ) under the Uruguay Round Agreement for the 1995–2000 period. Thus, wheat and wheat flour above the quota limit could be imported if the tariffs in the TRQ system are paid. However, wheat and wheat flour imports could be under the quota limit until 2000 or even longer, mainly because the tariffs in the TRQ system are not low enough to make wheat imports competitive.

Wheat is not considered to be a consumer-ready food product, but is mainly used by flour millers to produce wheat flour. Wheat flour is used by food manufacturers around the world to make bread, noodles, pasta, cake, couscous, and other wheat products. Noodles and bread are the favorite wheat products for Japanese consumers. Japan imports different classes of wheat (e.g. hard red winter (HRW), hard red spring (HRS), soft, white and durum) from different import sources, mainly the US, Canada, and Australia. Japan also imports a small amount of low quality wheat to feed directly to animals or to be processed for feed use by bran millers. Due to the difficulties in defining feed wheat and in obtaining data, most studies on international wheat trade do not separate trade for food wheat from that for feed wheat. Only a study by

Riley et al. (1994) provided a market analysis for world feed wheat trade.

Historically, food wheat accounts for about 80% of the Japanese total wheat imports (Food Control Statistical Yearbook, JFA, 1967–1994). Fig. 1 shows the shares of food wheat to total wheat in Japanese wheat imports by exporting country from 1983 to 1994. Japanese feed wheat imports are mainly from Australia and the US. Only small amounts of feed wheat are imported from Canada, mainly because Canadian wheat has fine baking quality associated with high protein. There are separate quotas for food wheat and feed wheat imports in Japan. Therefore, in estimating Japanese import demand for food wheat, it is appropriate to separate Japanese food wheat imports from all wheat imports and to treat food wheat as an input in wheat flour production.

The objective of this study is to estimate the Japanese demand for food wheat differentiated by class and country of origin in the Japanese milling industry. Conditional demand for each wheat class is derived from a multiple output multiple input translog cost function for the Japanese flour milling industry.

Since food wheat is used as an input to produce wheat flour products, the demand function for wheat or wheat classes should be derived on the basis of

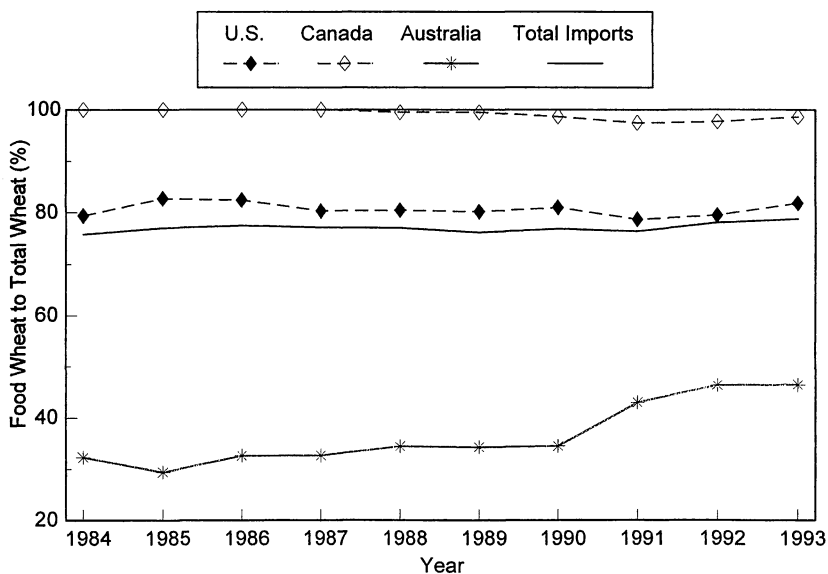


Fig. 1. Shares of food wheat to total wheat in Japanese wheat imports by country.

production theory. However, most previous studies used traditional approaches based on consumer demand theory. Capel and Rigaux (1974), Greenshields (1986), and Gallagher et al. (1981) used the direct demand and market share models to analyze wheat import demand under an assumption of different wheat classes in import markets. Some studies used the Armington model to analyze trade flows of wheat between importing and exporting countries by differentiating wheat by country of origin and other studies used the almost ideal demand system (AIDS) and the Rotterdam demand model to analyze import demand for wheat classes (Henning, 1986; Alston et al., 1990). Davis and Jensen (1994) argued that a production approach is conceptually more plausible than utility-based demand models in estimating demand for agricultural commodities used as inputs in the processing industry, but it is not an empirical panacea. They concluded that the bridge between theory and empirics is stronger for the production approach than the utility maximization approach.

Unlike previous studies in estimating import demand for wheat, our study focuses on estimation of Japanese demand for imported wheat at the industrial level using a production approach. Since the JFA imports wheat for the Japanese wheat flour milling industry, it is important to estimate Japanese demand for wheat to analyze the industry's consumption behavior for different classes of wheat imported from different import sources. The JFA imports wheat at world prices from exporting countries through its trading companies and resells the wheat to its wheat flour millers. Although the JFA imports wheat based on wheat flour industry's request for quantities of various classes of wheat, the JFA's import decision is influenced by Japanese trade and agricultural policies and its import behavior differs, to some extent, from the industry's response to prices of different wheat classes.

This study applied a dual translog cost function to derive wheat demand for imported wheat in the Japanese flour milling industry. Imported wheat differentiated by class and country of origin are treated as inputs, along with domestic wheat, labor, capital and other inputs, to produce wheat flour. Duality provides a convenient approach to identify substitutability between wheat classes and to measure effects of price changes on import demand for wheat classes in the Japanese flour milling industry.

## 2. Structure of the Japanese wheat milling industry

Although, rice has been the most important staple food in Japan, noodles made from wheat flour are also an important food item. It is considered that wheat cultivation was brought into Japan during fourth or fifth century (Isayama, 1982). However, wheat flour products became one of the staple foods in Japan after World War II, mainly because of the availability of cheap imported wheat from USA and the diversification of the Japanese diet into bread, cake, Chinese noodles, spaghetti and instant noodles. This diversified diet demanded foreign wheat since domestically grown wheat is not suitable for making those non-traditional flour products.

Wheat flour consumption per capita increased until the mid-1970s and since then has been relatively stable (Table 1). Total consumption of wheat flour has been growing at the rate of population growth for the last two decades. The trend of wheat flour consumption contrasts the case of rice consumption, which has been constantly declining since the 1960s (Table 1).

Both imported and domestic wheat sales in Japan have been controlled by the government through the JFA. Flour millers purchase wheat from the JFA at the pre-announced prices, process it, and sell wheat flour in the domestic market to food processing companies and households. The JFA monopolizes the Japanese wheat market, but its net revenues are used to pay costs of the domestic wheat subsidy program (Love and Murningtyas, 1992).

The number of millers decreased from 434 in 1965 to 180 in 1995. Many small inland mills were closed between 1965 and 1975. In this period domestic wheat production declined because the government purchase price of domestic wheat did not cover the production cost for the average producers (Yokoyama, 1993).

Table 1  
Wheat and rice consumption per capita (kg/year)<sup>a</sup>

	1955	1960	1965	1970	1975	1980	1985	1990	1995
Wheat	25.1	25.8	29.0	30.8	31.5	32.2	31.7	31.7	32.2
Rice	111	114	111	93.1	85.7	76.6	72.7	67.7	65.8

<sup>a</sup> Source: Ministry of Agriculture, Forestry and Fisheries. Tables of food supply and demand. Tokyo: various issues, 1955–1995.

Table 2  
Structural change in Japanese wheat flour industry<sup>a</sup>

	1965	1970	1975	1980	1985	1990	1995
Number of mills	434	343	225	220	207	193	180
Total number of employers	11785	11170	7682	7001	6269	5381	4745
Flour production (1000 ton/year)	2977	3402	3996	4184	4425	4652	4947
Flour production per employer (kg/year)	253	304	520	598	705	742	1041
Percentage of domestic wheat in total wheat processed	9.3	8.0	2.9	8.1	11.4	13.2	7.1
Real wage index of food processing industry (100 in 1995)	46.2	65.7	89.5	91.6	89.6	103.5	100

<sup>a</sup> Source: Japanese Food Agency. Wheat flour and feed processors: current situations. Tokyo: various issues, 1965–1995.

On the other hand, the number of large-scale mills increased at the same time period. They are located at ports to process imported wheat. Since large mills are generally more efficient than small mills, labor productivity in the milling industry has improved significantly (Table 2).

Domestic wheat production increased since 1973 because of high international wheat prices in early 1970s and government subsidies for wheat production to implement the rice acreage reduction program. Domestic wheat production decreased again since 1990 as a result of cutbacks in the rice land diversion target.

During the 20-year period between 1975 and 1995, the number of mills and total number of workers employed in the milling industry decreased constantly (Table 2) and consequently, average size of mills increased (Table 3) with further increases in labor productivity. The efficiency gain in this period can be explained by competition in the domestic flour market. The competition was not only among millers, but also with imported processed products of wheat flour. Only 29.7% of total number of mills are smaller than 50 tons of daily capacity in 1995, while 29.1% of them are more than 200 tons of daily capacity. In

terms of annual flour production, however, the share of the former mills is only 0.2% and that of the latter mills is 85.2% (JFA, 1967–1995). Those small mills are surviving because they typically specialize in producing specific types of flour from domestic wheat, and sometimes millers themselves are secondary processors who produce final products from their flour.

In December 1994, the GATT agreement became effective. As a part of the agreement, Japan accepted to import a minimum access of 5566 thousand tons of wheat (including processed products except for the wheat equivalent of imported wheat flour) in 1995, and agreed to increase it to 5740 thousand tons in 2000. Once the quota levels are met, additional wheat can be imported directly by millers after paying the appropriate tariffs. In 1995, the amount of the tariff was set at 63 ¥/kg, and that level is scheduled to decrease to 55 ¥/kg by 2000.

However, the Japanese milling industry may not import more than its minimum access mainly because the tariff rate was set too high to import wheat privately. In addition, the imported wheat under the minimum access commitments did not directly affect domestic production since the import commitments are much smaller than domestic demand for wheat.

Table 3  
Distribution of mills (categorized by daily ability to process)<sup>a</sup>

Capacity	1965	1970	1975	1980	1985	1990	1995
Less than 50 ton (%)	70.7	51.9	46.6	40.1	34.2	31.2	29.7
50–100 ton (%)	17.3	17.2	13.8	11.2	10.9	11.8	10.2
100–150 ton (%)	7.1	14.9	13.8	17.8	17.9	17.1	18.4
150–200 ton (%)	2.1	4.4	6.7	6.6	9.2	11.8	12.7
Above 200 ton (%)	2.8	11.7	19.1	24.4	27.7	28.2	29.1

<sup>a</sup> Percentages are based on the number of mills for each size category. Source: Japanese Food Agency. Wheat flour and feed processors: current situations. Tokyo: various issues, 1965–1995.

### 3. Model specification

A translog specification is used to represent the cost function of the Japanese flour milling industry. The translog cost function is well-known for its flexible functional form in terms of the local-order approximation to any arbitrary functional form.

Following Ray's specification Ray (1982), a *m*-output-*n*-input translog cost function for Japanese

wheat flour production can be written as

$$\begin{aligned} \ln C = & \ln k + \sum_{r=1}^m \alpha_r \ln q_r \\ & + \frac{1}{2} \sum_{r=1}^m \sum_{s=1}^m \lambda_{rs} \ln q_r \ln q_s \\ & + \sum_{i=1}^n \beta_i \ln w_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \delta_{ij} \ln w_i \ln w_j \\ & + \sum_{r=1}^m \sum_{i=1}^n \gamma_{ri} \ln q_r \ln w_i, \end{aligned} \quad (1)$$

where  $C$  is the total production cost;  $q_r$  ( $q_s$ ) the output quantity of product  $r$  ( $s$ ) and  $w_i$  ( $w_j$ ) is the price of input  $i$  ( $j$ ). The translog cost function is positive, symmetric, and linearly homogeneous in input prices. The restrictions on parameters imply that

$$\begin{aligned} \lambda_{rs} = \lambda_{sr}, \quad \delta_{ij} = \delta_{ji}, \quad \sum_{i=1}^n \beta_i = 1 \quad \text{and} \quad \sum_{i=1}^n \delta_{ij} = \sum_{j=1}^n \delta_{ij} \\ = \sum_{i=1}^n \gamma_{ri} = 0, \quad \text{for all } r, s, i \text{ and } j. \end{aligned}$$

Given the level of output under the assumption of perfect competition in the factor market, the cost minimizing input demand functions can be simply derived by differentiation of the cost function according to Shephard's lemma:

$$\frac{\partial \ln C}{\partial \ln w_i} = \frac{\partial C}{\partial w_i} \frac{w_i}{C}, \quad i = 1, \dots, n. \quad (2)$$

Since  $\partial C / \partial w_i = x_i$ , for  $i = 1, \dots, n$ , a derived input demand function can be expressed in a share form as

$$S_i = \frac{w_i x_i}{C} = \beta_i + \sum_{j=1}^n \delta_{ij} \ln w_j + \sum_{r=1}^m \gamma_{ri} \ln q_r, \quad i = 1, \dots, n \quad (3)$$

where  $x_i$  is the quantity of input  $i$  used in the production process.

With the assumption of marginal cost pricing for the outputs under perfect competition, we obtain the following relationship for each output  $r$

$$\frac{\partial \ln C}{\partial \ln q_r} = \frac{\partial C}{\partial q_r} \frac{q_r}{C} = \frac{p_r q_r}{C}, \quad r = 1, \dots, m. \quad (4)$$

This leads to the revenue share equations

$$y_r = \frac{p_r q_r}{C} = \alpha_r + \sum_{s=1}^m \lambda_{rs} \ln q_s + \sum_{i=1}^n \gamma_{ri} \ln w_i, \quad r = 1, \dots, m. \quad (5)$$

Following Uzawa, the Allen partial elasticities of substitution (AES) Allen (1938) can be calculated from the cost share function as

$$\sigma_{ij} = \frac{\delta_{ij} + S_i S_j}{S_i S_j}, \quad i \neq j, \quad (6)$$

$$\sigma_{ii} = \frac{\delta_{ii} + S_i^2 - S_i}{S_i^2}, \quad i = j. \quad (7)$$

The price elasticities of conditional demand for individual inputs can be obtained as

$$\varepsilon_{ij} = \frac{\delta_{ij} + S_i S_j}{S_i}, \quad i \neq j, \quad (8)$$

$$\varepsilon_{ii} = \frac{\delta_{ii} + S_i^2 - S_i}{S_i}, \quad i = j. \quad (9)$$

The Japanese milling industry mainly produces three types of wheat flour: weak, standard and strong flour. Different classes of wheat used by the Japanese millers are domestic soft wheat, US soft wheat, US semi-hard wheat, US hard wheat, Canadian hard wheat and Australian soft wheat.<sup>6</sup> Because durum wheat imports account for only 1.3% of the Japanese wheat imports in value, durum wheat was not included in this study. The other input variable included in this study is labor.<sup>7</sup>

<sup>6</sup> Based on the classification system used by the Japanese Food Agency, the imported food wheats are classified into five categories as follows: (1) US soft (WW), (2) US semi-Hard (HRW, 11.5% protein), (3) US hard (HRW, 13% protein; HRS, 14% protein), (4) Canadian hard (CWRS, 13.5% protein) and (5) Australian soft (ASW).

<sup>7</sup> Capital, energy and labor are additional aggregate inputs, besides wheat classes. However, only labor has played a significant role in the Japanese four milling industry. Since labor cost has been increasing in the last 30 years, millers have tried to reduce labor input by increasing mill size and shifting the location of mills. In addition, millers have tried to increase labor productivity by replacing small and inefficient mills with large, efficient mills and increasing utilization of their production capacity. As a result of increased labor productivity, total flour production increased from 4.2 million tons in 1967 to 5.7 million tons in 1993, although Japanese processing capacity of wheat remained almost the same during the same period.

A 7-input-3-output translog cost function for the Japanese flour milling industry was specified in this study. Cost share equations (Eq. (3)) and revenue share equation (Eq. (5)) were derived from the translog cost function. The parameters of the equations were estimated with time series data from 1968 to 1997. The Allen partial elasticities of substitution and price elasticities of demand for different wheat classes were calculated from the estimated structural parameters.

#### 4. Data descriptions and estimation procedure

Annual time series data from 1967 to 1997 were used in this study. All price and quantity data for domestic and foreign wheat were from the Food Control Statistical Yearbook (JFA, 1967–1994). Data on prices of three wheat flour classes were also taken from the same source. The number of workers employed in the Japanese milling industry and the output quantities of wheat flour by class was collected from the Wheat Flour and Feed Processors: Current Situations (JFA, 1967–1995). The wage index of workers in the Japanese food industry was obtained from the Japanese Statistical Yearbook (Statistics Bureau of Japan, 1967–1998).

Japanese flour millers purchase domestic and foreign wheat classes used for wheat flour production from the JFA. The prices of domestic and foreign wheat paid by millers were used as input prices in wheat flour production, while the wholesale prices of wheat flour were used as output prices.

Adding the error term  $e_i$  to Eqs. (3) and (5) results in a system of cost and revenue share equations for the Japanese wheat flour industry. This system was first estimated with the symmetry and linear homogeneity restrictions imposed. Since the sum of the  $S_i$ 's is equal to unity, the cost share equation for labor ( $S_7$ ) was dropped to ensure the non-singularity of the disturbance covariance matrix, and the price of labor was used as the numéraire. The remaining system was estimated using Zellner's iterative seemingly unrelated regression (ISUR) Zellner (1962) with parameter restrictions. The parameters associated with the dropped cost share equation were derived from the relationships with the estimated parameters. However, the resulting cost share functions failed to be con-

cave for some observations of the data. To ensure the concavity restrictions implied by microeconomic theory, the Wiley et al. (1973) re-parameterization procedure outlined by Kohli (1991) was used in the model estimation. The global concavity was ensured by imposing the concavity restrictions in 1990. This was done by re-estimating the model with input prices and output quantities normalized for 1990. Because of the reparameterization, the model becomes nonlinear in the parameters. The nonlinear system of cost and revenue share equations with the concavity restriction imposed was estimated using the nonlinear seemingly unrelated regression procedure from the SHAZAM, Version 7.0 (White, 1993).

After estimating coefficients of the nonlinear system of cost and revenue share equations, point estimates for the structural coefficients were estimated using Monte Carlo integration as illustrated by Chalfan et al. (1991). With the consistent coefficient estimates and variance-covariance matrix from Zellner's ISUR procedure, a random generator was employed to obtain a random sample for this multivariate normal distribution. From each draw for the parameter vector of the nonlinear system of cost and revenue share equations, the structural parameters were estimated, and the Allen elasticities of substitution and the price elasticities of the import demand were derived by wheat class and by origin of exporting country. The mean values of the derived parameters and elasticities of total draws became the estimated structural parameters and elasticities. The asymptotic standard errors were also obtained from the Monte Carlo integration through the standard statistical procedure.

#### 5. Empirical results

Table 4 presents the estimated coefficient of cost and revenue share equations. Most of the estimated parameters (53 of 87) are significant at the 5% level. Own price variables have negative sign as expected on the basis of economic theory and are significant at the 5% level in all cost share equations except for the labor equation, indicating that the Japanese milling industry is sensitive to prices of wheat classes.

The Allen partial elasticities of substitution (AES) are presented in Table 5. Most elasticities are signif-

Table 4  
Parameter estimates of the cost and revenue share equations for Japanese wheat milling industry, 1967–1997<sup>a</sup>

Variable	Cost share of							Revenue share of		
	Domestic soft	US soft	US semi-hard	US hard	Canadian hard	Australian soft	Labor	Weak flour	Standard flour	Strong flour
Intercept	0.1462* (0.0099)	0.1789* (0.0114)	0.0953* (0.0080)	0.2375* (0.0116)	0.2651* (0.0115)	0.0763* (0.0087)	0.0007 (0.0174)	0.1226* (0.0084)	0.2240* (0.0099)	0.5476* (0.0193)
Input price of										
Domestic soft	-0.5628* (0.0685)							-0.6420* (0.0995)	0.8348* (0.1014)	1.2542* (0.2752)
US soft	0.4926* (0.0297)	-0.4900* (0.0861)			(Symmetric)			0.4943* (0.0471)	-0.0132 (0.0731)	0.3013 (0.1803)
US semi-hard	0.2213 (0.0824)	0.2151* (0.0632)	-0.8236* (0.2620)					-0.2306 (0.2138)	-1.5278* (0.2470)	-4.3422* (0.6568)
US hard	-0.1273 (0.1170)	-0.1739 (0.1204)	0.3144 (0.2519)	-0.8823* (0.4076)				-1.0347* (0.2261)	0.2452 (0.2725)	-0.1376 (0.6299)
Canadian hard	-0.0602 (0.0777)	-0.1833* (0.0824)	0.3061 (0.1836)	0.6688* (0.3111)	-0.8048* (0.2779)			0.6757* (0.2012)	0.7055* (0.2273)	2.6394* (0.5555)
Australian soft	0.0812 (0.0539)	0.1188 (0.0668)	-0.2501* (0.1133)	0.2376* (0.1153)	0.0657 (0.0985)	-0.3027* (0.0863)		0.8738* (0.0918)	-0.4904* (0.1268)	-0.1126 (0.3136)
Labor	-0.0448* (0.0150)	0.0208 (0.0140)	0.0169 (0.0180)	-0.0373 (0.0200)	0.0077 (0.0165)	0.0496* (0.0115)	-0.0129 (0.0177)	-0.1944* (0.0189)	0.1983* (0.0181)	0.1984* (0.0499)
Output quantity of										
Weak flour	0.2264* (0.0559)	0.0211 (0.0665)	-0.0993* (0.0275)	0.1087* (0.0485)	-0.1144* (0.0360)	-0.1587* (0.0350)	0.0162 (0.0173)	0.4038* (0.0319)		(Symmetric )
Standard flour	0.2682* (0.0408)	-0.0596 (0.0526)	-0.0641 (0.0218)	-0.1156 (0.0423)	-0.0356 (0.0316)	0.0176 (0.0296)	-0.0109 (0.0162)	-0.1672* (0.0183)	0.2530* (0.0184)	
Strong flour	-0.4946* (0.0684)	0.0385 (0.0827)	0.1634* (0.0371)	0.0069 (0.0647)	0.1500* (0.0444)	0.1411* (0.0441)	-0.0053 (0.0243)	-0.0425 (0.0344)	0.0478 (0.0406)	0.4997* (0.1293)

<sup>a</sup> Note: Concavity was imposed in 1990. Asymptotic standard errors are in parentheses and an asterisk (\*) indicates significance at the 0.05 level.



Table 5  
 Estimated Allen elasticities of substitution at the sample mean<sup>a</sup>

Input factor	Factor price of						
	Domestic soft	US soft	US semi-hard	US hard	Canadian hard	Australian soft	Labor
Domestic soft	-66.6360* (7.0679)						
US soft	25.8887* (1.5137)	-16.2344* (2.1713)					
US semi-hard	19.9609* (7.0607)	10.1076* (2.6804)	-66.6312* (18.8364)				
US hard	-6.3465 (6.7511)	-3.9595 (3.4333)	16.2072 (12.1829)	-33.4398* (13.2818)			
Canadian hard	-3.0061 (5.1697)	-5.0338 (2.7107)	18.0872 (10.2476)	26.1360* (11.6942)	-40.4927* (12.0706)		
Australian soft	7.4161 (4.2655)	5.6409* (2.61400)	-15.5779* (7.5089)	11.6039* (5.1459)	4.3825 (5.0748)	-25.3304* (5.3015)	
Labor	-2.5344* (1.1831)	1.8125* (0.5466)	2.1157 (1.1952)	-0.6626 (0.8898)	1.3936 (0.8507)	4.0317* (0.7092)	-7.5981* (1.1043)

<sup>a</sup>Note: Asymptotic standard errors are in parentheses and an asterisk (\*) indicates significance at the 0.05 level.

ificant at the 5% level. The positive signs of the AES indicate substitute relationships between any pairs of wheat classes. Strong substitution suggests a high level of competition. The negative signs of the off-diagonal AES imply complementary relationships between any pairs of wheat classes. This could be mainly because Japanese millers blend different classes of wheat for many different types of wheat flour production. The AES between any pairs of soft wheats (Japanese soft, US soft, and Australian soft) are positive, indicating that they compete in the Japanese milling industry. However, the AES between soft and hard wheats are negative, indicating that they are complementary to some extent. The AES between any pairs of hard wheats (US hard, US semi-hard, and Canadian hard) positive, indicating that they are competing in the Japanese milling industry.

Table 6 present price and cross price elasticities of demand for wheat classes and labor. The elasticities estimated in this study are much more elastic than those estimated by Wilson (1994) and Lee et al. (1994). This is mainly because (1) this study used a production theory approach by treating wheat as an input in the Japanese milling industry, while Wilson (1994) and Lee et al. (1994) used a translog demand system and the AIDS, respectively, by treating wheat as a consumer good and (2) this study focused on demand for different wheat classes in the Japanese milling industry, while the other studies analyzed Japanese import demand for different wheat classes from foreign sources.

Own-price elasticities are elastic for all the wheat classes, but the demands for imported soft wheat classes are less elastic than all the hard wheat classes and Japanese soft wheat. These relationships also reflect the substitutability between wheat classes; US and Canadian hard wheat can be substituted for each other, but other wheat classes are less substitutable. Calculated own price elasticities range between  $-7.86$  for demand equation for US semi-hard wheat and  $-3.23$  for Australian soft wheat. The own price elasticity of labor is  $-0.97$ . These elasticities clearly indicate that the Japanese milling industry is very sensitive to prices of wheat classes, but not sensitive to labor costs, mainly because substitutes for labor are limited in the industry.

Both Japanese and US soft wheat have a negative relationship with US and/or Canadian hard wheat in

Japanese wheat flour production, indicating that the soft and hard wheats are complements. However, the complementary relationship is not significant at the 5% level. Soft wheat is seldom blended with hard wheat and has different uses. US and Canadian hard wheat is primarily used to produce bread, while Japanese and US soft wheat are used to produce Chinese style noodle, cookies and cakes. On the other hand, Japanese and US soft wheat have a positive relationship with US semi-hard and Australian soft wheat in the Japanese milling industry, indicating that they compete with each other. However, the substitution elasticity between Japanese soft and Australian soft wheat is not significant. These two wheat types are very similar and are often mixed to produce Chinese style noodles. Thus, they are to some extent complements, but also compete with each other. This relationship depends upon supply conditions for domestic soft wheat. When supply of the domestic wheat is short, they are complements, but when supply is sufficient, they compete.

US hard and semi-hard wheats compete with Canadian hard wheat in the Japanese wheat flour milling industry. However, the competitive relationship between Canadian hard and US hard wheat is stronger than that between Canadian hard and US semi-hard wheat, mainly because semi-hard wheat is not a perfect substitute for hard wheat. US hard and semi-hard also compete with each other, but the relationship is not significant at the 5% level due to imperfect substitutability. The negative significant elasticities between Australian soft and US semi-hard wheat indicate that they are blended together in the Japanese milling industry.

Cross price elasticities presented in Table 6 are consistent with AES in Table 5. In general, cross elasticities between hard wheat classes (e.g. US hard wheat, US semi-hard wheat and Canadian hard wheat) and those between soft wheat classes (e.g. US soft, Australian soft, and Japanese soft) are elastic, while those between hard and soft wheat classes are inelastic. This is because similar wheat classes compete with each other, while different classes are to some extent complements.

Japan imports more wheat from the US mainly because the US produces both hard and soft wheat which can be used to produce bread, cakes, cookies and Chinese style noodles. US soft wheat competes

Table 6  
 Estimated price elasticities of factor demand at the sample mean<sup>a</sup>

Demand for	Factor price of						
	Domestic soft	US soft	US semi-hard	US hard	Canadian hard	Australian soft	Labor
Domestic soft	-6.5913* (0.6991)	5.1806* (0.3029)	2.3553* (0.8331)	-1.1121 (1.1830)	-0.4564 (0.7850)	0.9483 (0.5455)	-0.3245* (0.1515)
US soft	2.5608* (0.1497)	-3.2487* (0.4345)	1.1927* (0.3163)	-0.6938 (0.6016)	-0.7643* (0.4116)	0.7213* (0.3343)	0.2320* (0.0700)
US semi-hard	1.9744* (0.6984)	2.0226* (0.5364)	-7.8622* (2.2226)	2.8400 (2.1348)	2.7463 (1.5560)	-1.9921* (0.9602)	0.2709 (0.1530)
US hard	-0.6278 (0.6678)	-0.7923 (0.6870)	1.9124 (1.4375)	-5.8598* (2.3274)	3.9684* (1.7756)	1.4839* (0.6580)	-0.0848 (0.1139)
Canadian hard	-0.2973 (0.5114)	-1.0073* (0.5424)	2.1342 (1.2092)	4.5799* (2.0492)	-6.1483* (1.8328)	0.5604 (0.6490)	0.1784 (0.1089)
Australian soft	0.7336 (0.4219)	1.1288* (0.5231)	-1.8381* (0.8860)	2.0334* (0.9017)	0.6654 (0.7705)	-3.2392* (0.6780)	0.5161* (0.0908)
Labor	-0.2507* (0.1170)	0.3627* (0.1094)	0.2497 (0.1410)	-0.1161 (0.1559)	0.2116 (0.1292)	0.5156* (0.0907)	-0.9727* (0.1414)

<sup>a</sup>Note: Asymptotic standard errors are in parentheses and an asterisk (\*) indicates significance at the 0.05 level.

with Japanese soft wheat, but other wheat classes produced in the US are complementary with Japanese soft wheat. In general, US wheat exports to Japan benefit from the existence of multiple classes and multiple end-use characteristics. If Japan liberalizes its domestic wheat market, the milling industry would use more imported wheat instead of domestic soft wheat because prices of domestic wheat is higher than those of imported wheat. US market share of soft wheat could increase faster than other wheat classes since US soft wheat is a good substitute for Japanese soft wheat.

## 6. Summary and conclusions

This study applied a multiple output and multiple input translog cost function for the Japanese flour milling industry to analyze Japanese demand for food wheat. Unlike previous studies, Japanese demand for food wheat was separated from that for feed wheat because the JFA sets up separate quotas for food wheat and feed wheat imports. Wheat is considered as an input in Japanese wheat flour production. A production theory approach was used to derive Japanese demands for imported wheat differentiated by class and origin of country. The system of cost and revenue share equations for Japanese wheat flour production was estimated using the nonlinear seemingly unrelated regression with symmetry, linear homogeneity and concavity restrictions.

The results suggest that Japanese demand for food wheat is highly elastic. US soft wheat mainly competes with Japanese domestic soft wheat in the Japanese wheat market. US hard and semi-hard wheats face strong competition from Canadian hard wheat. Australian soft wheat also competes with US soft and hard wheat, but the competition is less intense.

The multiple classes and the multiple end-use characteristics of US wheat enable the US to maintain its large market share in the Japanese wheat market. If Japan liberalizes its domestic wheat market, the milling industry would use more imported wheat instead of domestic soft wheat and US market share of soft wheat could increase faster than other wheat classes.

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