Journal of Agricultural and Applied Economics, 41,1(April 2009):241–252

Effects of Price and Quality Differences in Source Differentiated Beef on Market Demand

Youngjae Lee and P. Lynn Kennedy

In order to estimate demand elasticities of source differentiated beef in South Korea, this study used the quantity of an endogenous demand system derived through maximizing the economic welfare of market participants including local beef consumers and local and foreign beef suppliers. The demand system is then weighted with respect to quality adjustment parameters to identify the effects of quality differences in source differentiated beef on market demand. As implied by the high relative price of locally produced "Hanwoo" beef, substitutability between local and imported beef is shown to be very weak and the own price elasticity of South Korean beef is shown to be inelastic. Related to quality differences between source differentiated beef, South Korean beef consumers show a preference for Australian beef relative to U.S. and Canadian beef, perhaps due to BSE concerns.

Key Words: beef, quality complement, quality difference, quality substitute

JEL Classifications: F10, F11, F13

With the development of free trade in the South Korean beef market, previous studies expected the price difference between local and imported beef to narrow as demand for lower priced imported beef products increased. Hayes, Ahn, and Baumel projected retail price and total consumption of beef in South Korea under trade liberalization scenarios. According to their estimation, the local beef price was expected to decrease with an increase in lower priced beef imports. Byrne et al. also projected a narrowing price gap between local and imported products as beef imports increased.

Contrary to expectations, price differences between local and imported beef have expanded since 1988 when the South Korean government opened their beef market through a quota system.[1] This gap remains, even after South Korea liberalized beef trade in 2001. Price differences may reflect perceived quality differences on which consumers place the most importance. Wilson and Gallagher showed that quality differences influence end-use performance and, consequently, value. Henneberry and Hwang emphasized that quality differences should be recognized when analyzing the South Korean meat import demand. Jung et al. showed that South Korean beef consumers prefer locally produced Hanwoo beef to that of

Youngjae Lee and P. Lynn Kennedy are assistant professor, Research and Crescent City Tigers Alumni, and professor, respectively, in the LSU AgCenter.

The authors wish to thank two anonymous reviewers and the editors for their helpful comments regarding this paper. Support for this analysis was provided through the Center for North American Studies and USDA, CSREES. This article was approved for publication by the Louisiana Agricultural Experiment Station.

[1] The liberalization schedule for beef imports in South Korea was well described in the paper presented by Kim and Veeman in 2001.

lower priced imported beef. In fact, the 2005 price of imported beef was \$4.68 per kg in the South Korean beef market while the retail price of locally produced beef was \$36.11 per kg (exchange rate is 1,034 Korean Won/\$1, 2005), this is a 770% price difference in 2005 as compared with only 190% in 2001.

The purpose of this study is to determine effects of price and quality differences in source differentiated beef on market demand in South Korea. In addressing these issues, this study uses a demand system to identify quality effects of source differentiated beef products. In order to achieve this goal, this study proceeds as follows. In the next section, a quantity endogenous demand system is discussed. Following this discussion, an empirical estimation of the demand system model is conducted, accompanied by a discussion of other issues related to beef policy and market access in South Korea. The role of the quality adjustment parameter in the demand system is discussed in the fourth section, in which the effects of quality differences on market demand are discussed, along with simulation results. Finally, conclusions will be provided in the last section.

Demand System

We assume that there are five major sources of beef in the South Korean beef market: South Korea (SK), the United States (US), Australia (AU), Canada (CA), and New Zealand (NZ).[2] These five linear price equations are as follows:

$$(1) \qquad p_i = a_i - b_i q_i, \quad i = 1,2,3,4,5,$$

where we assume that a_i and b_i are unconditional coefficients that can be converted to demand equations as follows:

$$(2) \qquad q_i = A_i - B_i p_i, \quad i = 1,2,3,4,5,$$

where $A_i = a_i/b_i$ and $B_i = 1/b_i$. Later, the study will test this unconditional assumption with empirical data. Given the inverse price equation, the gain of the South Korean beef consumers equates to the following:

$$(3) \qquad CS = \sum_{i=1}^{5} \left| \frac{a_i}{b_i} p_i - \frac{1}{2b_i} p_i^2 \right|_{p_i^0}^{p_i^1} .^3$$

Similarly, the sum of the gain of each supplier equates to the following:

$$(4) \qquad PS = \sum_{i=1}^{5} |q_i p_i - c_i q_i|_{p_i^0}^{p_i^1},$$

where c_i is the average unit cost of beef i including production cost, transportation cost, and tariffs. Here, it should be noted that PS includes gains to producers, traders, and marketers. Some of the PS will be captured by local firms and some by foreign firms. Since market equilibrium of price and quantity is a result of a market mechanism rather than that of government intervention under a free trade policy, the economic gain of market participants is the summation of the welfare gain of both consumer and supplier and is expressed as:

$$(5) \qquad EWF = \sum_{i=1}^{5} \left| \frac{a_i}{b_i} p_i - \frac{1}{2b_i} p_i^2 + q_i p_i - c_i q_i \right|_{p_i^0}^{p_i^1} .$$

EWF represents total welfare related to the South Korean beef market. While all of the consumer surplus remains in South Korea, some of the producer surplus will be captured by foreign producers and foreign trading firms and another portion will be captured by South Korean trading firms and retailers. Aggregate welfare functions are often used as a means of evaluating various government or trade policies (Diewert; Hausman; and Jorgenson, Lawrence, and Thomas; Sarris and Freebairn). This paper will use the EWF to derive elasticities and evaluate the effect of product quality changes on consumer choice. The economic welfare function defined in Equation (5) can be rewritten to derive a quantity endogenous demand system as follows:

[2] This study used these five countries because imports from other countries are very small and intermittent.

[3] $\sum_i | p_i |_{p_i^0}^{p_i^1} = \sum_i p_i^1 - \sum_i p_i^0$

$$EWF = \sum_{i=1}^{5}\sum_{j=1}^{5} \phi_0 p_i + \phi_1 p_i Q + \phi_2 p_i p_j + \phi_3 p_i q_i, \quad (6)$$

where $Q = \sum_i q_i$ is the summed quantity of beef supplied to the South Korean market. The demand system can be derived from the maximizing condition of the *EWF*. In order to define the maximizing condition of the *EWF*, we differentiate Equation (6) with respect to the five individual beef prices.

$$\frac{\partial EWF}{\partial p_i} = \phi_0 + \phi_1 Q + \sum_j \phi_2 p_j + \phi_3 q_i = 0. \quad (7)$$

From Equation (7), we obtain a quantity endogenous demand system that maximizes the economic welfare of participants in the South Korean beef market as follows:

$$q_i = \alpha_{1i} + \alpha_{2i} Q + \sum_j \alpha_{3j} p_j, \quad i,j = 1,2,3,4,5, \quad (8)$$

where α_{2i} represents the marginal effect of market size on the beef that comes from country i and α_{3j} represents the own price effect ($j = i$) and cross price effect ($j \neq i$) on beef i. While Equation (8) appears similar to the traditional demand equation, we have derived this through alternative means. One advantage of this is to reflect total welfare arising from the South Korean beef market. Appendix 1 illustrates the relationship between the parameters of Equation (2) and Equation (8).

Empirical Estimation

Market Access and Policies for Beef in South Korea

Under South Korea's market access commitment, South Korea phased out nontariff barriers to beef imports, including state trading and price markups, by January 2001. Before then, imported beef was under a quota that increased until 2000, the final year. Steep price markups have been eliminated. Before 2001, an increasing share of the quota was allocated to private "supergroups" representing private buyers such as supermarkets, restaurants, and hotels. Through the Simultaneous-Buy-Sell (SBS) system, supergroups were free to negotiate specific cuts and qualities with foreign exporters. The rest of the quota was administered by the Livestock Products Marketing Organization (LPMO), a state trading enterprise. The LPMO allocated some imported beef to special shops licensed to sell it. As of January 1, 2001, beef became freely importable, at a 41.2% tariff. Special treatment of imported beef, such as the requirement that it be retailed in shops that did not also sell domestic beef, was supposed to end. According to the free trade agreement between the United States and South Korea, South Korea is scheduled to eliminate the 41.2% tariff through a 15-year straight-line tariff phase out for all U.S. beef products.

Data

Conventional demand system analyses of meat consumption data have generally used aggregate annual, quarterly, or monthly time series data of purchases and prices at the retail level (Kinnucan et al.; McGuirk et al.; Mittelhammer, Shi, and Wahl). The data used in this study consist of monthly time series observations from January 1995 to December 2004. This time period was purposefully selected because (1) significant progress of liberalization was made in South Korea, (2) South Korean beef imports were different from the scheduled level of import commitment, reflecting economic instability and consumer confidence for consumption of beef during this period, and (3) U.S. beef imports were banned after 2005 due to a case of BSE in the United States. Related to the liberalization of the South Korean beef market, (1) an SBS system commenced at the beginning of 1995 and (2) on January 2001, beef became freely importable, at a 41.2% tariff without any markup payments. South Korean beef retail price data were obtained from the monthly consumer price index announced by the Korean Statistical Information Service (KOSIS). The study used the December 2004 nominal price as a reference price to transform the index into beef price. Because retail-level prices for imported beef were not available, imported beef prices were obtained by adding tariff and markup payments

Table 1. Summary Statistics for Quantity and Price of Each Source Differentiated Beef, 1995–2004

	Mean	Standard Deviation	Minimum	Maximum
Quantity				
q_{sk}	38,318	12,318	13,088	74,196
q_{us}	8,514	5,680	90	23,912
q_{au}	5,588	2,328	785	12,372
q_{ca}	647	641	1	3,012
q_{nz}	1,969	3,527	128	38,570
Price				
p_{sk}	21.87	7.28	13.08	34.12
p_{us}	5.92	1.66	3.13	10.88
p_{au}	3.68	0.90	2.56	5.74
p_{ca}	5.28	2.33	2.94	13.86
p_{nz}	3.76	0.71	2.66	5.70

Sources: KCS, KOSIS, and Nonghyup
q_{sk}: South Korean Beef Consumption
q_{us}: U.S. Beef Consumption
q_{au}: Australian Beef Consumption
q_{ca}: Canadian Beef Consumption
q_{nz}: New Zealand Beef Consumption
p_{sk}: South Korean Beef Price
p_{us}: U.S. Beef Price
p_{au}: Australian Beef Price
p_{ca}: Canadian Beef Price
p_{nz}: New Zealand Beef Price

to unit value import prices.[4] The unit value import prices were obtained from the Korean Customs Service (KCS). Price data were then converted from the South Korean currency, the Won, into U.S. dollars using monthly average exchange rates from the Federal Reserve Bank of New York. South Korean beef consumption data were reported at the wholesale level and were obtained from Nonghyup, the National Agricultural Cooperative Federation in South Korea. Data on import quantity were collected from KCS. The summary of sample statistics price and quantity for source-differentiated beef is presented in Table 1.

A) System Misspecification Tests. This study used the seemingly unrelated regression (SUR) model to estimate the unknown parameters of Equation (8). The theoretical restrictions of homogeneity and symmetry were imposed on the SUR model. In order to confirm the statistical validity of the model, this study tested whether econometric assumptions were appropriate for the data being analyzed. If the observed data provide statistical adequacy, the underlying relationships defined in the economic model can be appropriately identified.[5]

[4] This study used unit prices weighted by tariff and markup payments as proxies of market prices of imported beef because of the limited availability of data for imported beef market prices. However, according to Henneberry and Hwang, unit values may not be a perfect measure of market prices for imported beef because trade restriction (such as quotas) might not change the unit value for beef from a particular import source, but they might change market prices of beef due to supply restrictions.

[5] Normality, functional form, heteroskedasticity, autocorrelation, and parameter stability are tested individually and jointly. For this purpose, this study followed the testing strategy proposed by McGuirk et al. to test for equation-by-equation misspecification. Equation-by-equation tests, as suggested by McGuirk et al., are used to test for the misspecification of each equation in the free trade demand system. Even though single-equation tests do not examine misspecification in the contemporaneous covariance between the residuals of different equations, such tests can be useful in detecting misspecification and providing methods for model respecification when a single source of misspecification is identified.

Table 2. *p*-Values for Equation-by-Equation Misspecification Tests

	q_{sk}	q_{us}	q_{au}	q_{ca}	q_{nz}
			Before Model Respecification		
Normality[a]	0.0001	0.2168	0.0279	<0.0001	<0.0001
Functional form[b]	0.2010	<0.0001	0.4513	0.0001	<0.0001
Heteroskedasticity[c]	<0.0001	<0.0001	0.0109	0.0815	<0.0001
Autocorrelation[d]	<0.0001	<0.0001	0.0324	<0.0001	0.8743
Parameter stability[e]	<0.0001	<0.0001	0.0671	<0.0001	0.0148
			After Model Respecification		
Normality	0.7048	0.2596	0.2398	0.1768	0.6094
Functional form	0.0616	<0.0001	0.3049	0.0029	0.1034
Heteroskedasticity	0.3114	0.0338	0.5450	0.2073	0.1901
Autocorrelation	0.6493	0.8679	0.3896	0.7471	0.7764
Parameter stability	0.0073	0.0001	0.9951	0.1812	0.2819

q_i is a single equation for beef i sourced from country i.

$_{sk}$ South Korea, $_{us}$: United States, $_{au}$: Australia, $_{ca}$: Canada, and $_{nz}$: New Zealand.

[a] The number in the normality row indicates that the residual of equation is normally distributed at 5% level of significance if the number is less than 0.05.

[b] The number in the functional form row indicates that an equation is incorrect functional form at 5% level of significance if the number is less than 0.05.

[c] The number in the heteroskedasticity row indicates that the variances of residuals of equation are not white noise at 5% level of significance if the number is less than 0.05.

[d] The number in the autocorrelation row indicates that residuals of an equation are serially correlated at 5% level of significance if the number is less than 0.05.

[e] The number in the parameter stability row indicates that $\hat{\alpha}$ differs between the first and second half of the sample at the 5% level of significance if the number is less than 0.05.

The initial test results suggested a need for model respecification. In particular, the assumption of normality was violated in all but two equations. This could violate critical assumptions required for hypothesis testing, consequently leading to inappropriate inference. To prevent key econometric assumptions from being violated and, yet, maintain the key aspects of our model, we estimated the model again after: (1) eliminating outliers, (2) arbitrarily resorting the data, and (3) applying weighted regression methods.[6]

[6] In order to deal with the violation of the assumptions necessary to conduct of the econometric regressions, this study followed solutions suggested by current econometric knowledge. For example, this study separately and/or jointly attempted strategies of weighted least squares, exclusion of some outliers in the model, and trend elimination to eliminate or reduce the violation of the statistical assumptions of the model. In this effort, this study found the respecified model mentioned in the text to be the best solution for data being used in the model.

Following these recommendations, the study conducted each of the individual and joint tests, significantly reducing the potential for parameter and testing bias. Table 2 shows the individual test results both before and after model respecification.

This study adopted the assumption of unconditional demands in Equations (1) and (2), which allows for the estimation of price elasticity coefficients, $\hat{A}_i$ and $\hat{B}_i$, and price flexibility coefficients, $\hat{a}_i$ and $\hat{b}_i$, of the five source-differentiated categories of beef. If the expected variances of Equations (1) and (2) are zero, then the unconditional assumption of the coefficients will be satisfied. However, the null hypothesis tests were rejected at the 10% level of significance.

B) Estimation. Having tested for and accounted for problems in the data that could have led to poorly estimated parameters, the next step was the estimation of unknown parameters of the five source-differentiated beef products. This study estimated parameters of five source-differentiated beef products

Table 3. Price and Market Elasticities at Mean Values

	p_{sk}	p_{us}	p_{au}	p_{ca}	p_{nz}	Q
q_{sk}	$-\underline{0.3673}$	$\underline{0.0300}$	$\underline{0.0091}$	0.0008	$\underline{0.0101}$	$\underline{0.4683}$
q_{us}	$\underline{0.8114}$	$-\underline{0.7217}$	$-\underline{0.1107}$	−0.0302	$\underline{0.5104}$	$\underline{1.3196}$
q_{au}	$\underline{0.5900}$	$-\underline{0.2660}$	$-\underline{0.2836}$	$-\underline{0.2285}$	$\underline{0.5648}$	$\underline{0.5677}$
q_{ca}	0.3472	−0.4629	$-\underline{1.4553}$	$-\underline{0.4071}$	$\underline{2.0326}$	$\underline{1.6883}$
q_{nz}	$\underline{1.8423}$	$\underline{3.4433}$	$\underline{1.5852}$	$\underline{0.8958}$	$-\underline{4.6754}$	$\underline{1.2758}$

p_i is price of beef i sourced from country i.
Q is total quantity of beef supplied into South Korean beef market.
Underline represents statistical significance at least at 10% level.

using the model as presented in Equation (8). Since the model is composed of quantity share equations[7] for the five source-differentiated categories, inclusion of all equations in one system would result in singularity problems. Thus, one equation was dropped. The coefficients of the dropped equation were then calculated using the adding-up restriction. While seasonal dummy variables were included in the pretest estimation, degree of freedom problems precluded us from including them in the final version of the model.[8]

The model identifies the marginal effects of prices and market size on market demand of each source-differentiated beef category at the point of economic welfare maximum. Among 20 estimated parameters, 17 are significant at least at the 10% level of significance. Negativity of own price elasticity was satisfied. For easy interpretation, this study converted marginal values into elasticities, which were calculated at the data means and are presented in Table 3.

As expected, all own price elasticities are negative. In order to explain the extremely high relative price of South Korean beef, this study hypothesized that demand for own South Korean beef would be the most inelastic. However, the own price elasticity of Australian beef is shown to be the most inelastic. This may be because the fear of BSE in Canada and the United States accelerated Australian beef imports despite an increase in the Australian beef price. In fact, an increase in the imported price of Australian beef from \$2.61/kg in 2001 to \$5.52/kg in 2005 was accompanied by an increase in imports of Australian beef. Related to cross price elasticities for South Korean beef, four source-differentiated beef products are shown to be substitutes even though the magnitudes of cross effects are estimated to be very small. In comparing the relative magnitudes, the cross-price elasticity of U.S. beef was shown to be the largest of the five cross-price elasticities in the South Korean beef equation. For U.S. beef, South Korean and New Zealand beef are substitutes, while Australian and Canadian beef are complementary goods. For Australian beef, South Korean and New Zealand beef are substitutes, while U.S. and Canadian beef are complements. For Canadian beef, South Korean and New Zealand beef are substitutes, while U.S. and Australian beef are complements. For New Zealand beef, each of the other four source-differentiated beef products are substitutes.

According to Song, Shin, and Kim (pp. 19–20), the price difference between local and imported beef after the liberalization of the South Korean beef market in 2001 became more pronounced because there was little substitutability between local and imported beef.

[7] The quantities in Equation (8) can be normalized as $q_i^* = \frac{q_i}{Q}$, where q_i^* is normalized quantity i and $Q = \sum_{i=1}^{n} q_i$ is the sum of n quantities. As a result, the sum of normalized quantities will be 1, $\sum_{i=1}^{n} q_i^* = 1$, similar to the sum of budget shares used in the traditional demand systems.

[8] Dummy variables reflecting seasonality in beef demand were included in the pretest estimation. Although some variables were significant, they were not included in the final version of the model because of their small sample size and the subsequent degrees of freedom problem.

That is, there is a strong niche market for the local Hanwoo beef. In our study, the cross price elasticities of U.S., Australian, Canadian, and New Zealand beef for South Korean beef are estimated to be very small and the own price elasticity of South Korean beef is very inelastic, which is consistent with the findings of Song, Shin, and Kim and is consistent with the existence of a relatively high price of local beef.

Related to growing market size, our results show that, for a 1% increase in the South Korean beef market size, South Korean beef consumption increases by 0.468%, U.S. beef by 1.319%, Australian beef by 0.568%, Canadian beef by 1.688%, and New Zealand beef by 1.276%. These results indicate that, given an increase in the size of the South Korean beef market, the market share of South Korean and Australian beef decreases, while market share of U.S., Canadian, and New Zealand beef increases. In fact, prior to December 2003 when the South Korean government prohibited beef imports from the United States because of reported BSE outbreaks, the U.S. beef market share had increased from 10% in January 1995 to 38% in November 2003. At the same time, the South Korean and Australian beef market share decreased from 75% for South Korea and 11% for Australia to 48% and 9%, respectively. In particular, these results imply that, given an increase in the income of South Korean beef consumers, Australian grass-fed beef is not preferred to U.S. grain-fed beef.[9]

The Role of Quality Adjustment Parameters

In order to examine the role of quality adjustment parameters in the free trade demand system, the inverse demand price as defined in Equation (1) is weighted by a quality adjustment parameter as follows:

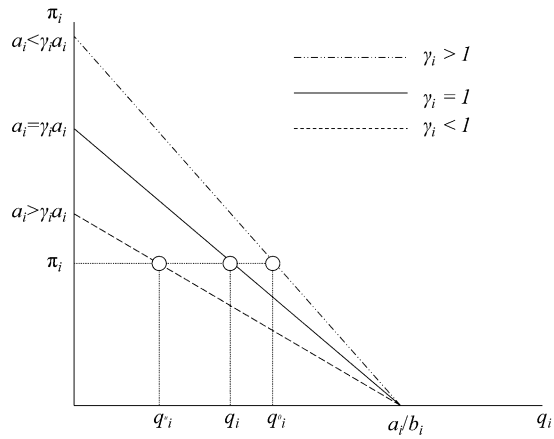

Figure 1. Relationship Between Quality Difference and Market Demand

$$\pi_i = \gamma_i p_i = \gamma_i(a_i - b_i q_i), \tag{9}$$

where γ_i represents a quality adjustment parameter for each differentiated source of beef i and π_i represents actual market price weighted by the parameter. In brief, to visually review the quality adjusted inverse price relationship, consider the three different cases exhibited in Figure 1 which depicts quantity and price relationships under various assumptions about product quality. If the parameter is one, then the actual market price, π_i, is equal to the true price, p_i. If the parameter is less (greater) than one, implying that the quality is underestimated (overestimated), then market demand will decrease (increase) from q_i to q_i^u (q_i^o) at a constant actual market price, π_i.

Effects of Quality Differences on Market Demand

Before developing this section, let us review two cases of the relationship between quality and market demand. Figure 2 shows that an increase in own quality, γ_i, increases market demand of the own good from q_i^0 to q_i^1 under given π_i, π_j, q_j, and γ_j. Figure 3 shows the impact of cross quality; an increase in cross quality, γ_j, decreases market demand of q_i from q_i^1 to q_i^0 given π_i and π_j.

Now, to measure quantitatively these own and cross quality impacts on market demand,

[9] Henneberry and Huang showed that the South Korean market is differentiated in terms of buyers' attitudes toward meat imported from various sources. The grain-fed beef imported from the United States has generally been viewed as having a higher quality than the grass-fed beef imported from Australia.

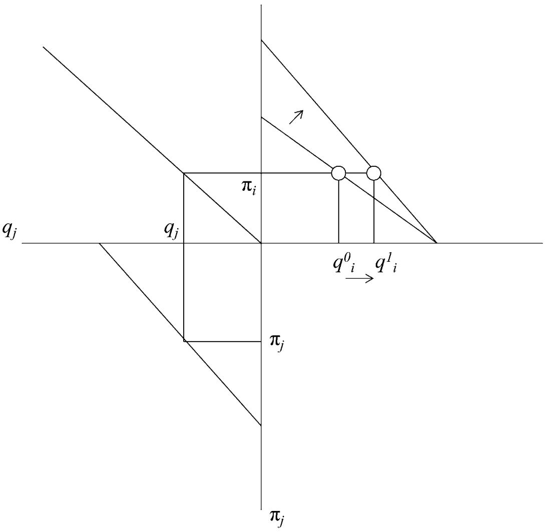

Figure 2. Relationship Between Quality Difference for Own Good and Market Demand

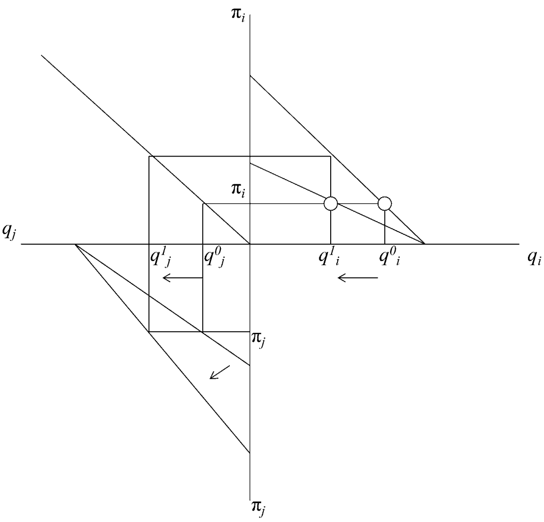

Figure 3. Relationship Between Quality Difference for Cross Good and Market Demand

Equation (9) can be differentiated with respect to γ_i and γ_j. Then, own and cross quality adjusted differential equations can be obtained as follows:

$$(10)\quad \begin{aligned}\frac{\partial q_i}{\partial \gamma_i} &= A + \frac{\sum_{j\neq i} b_j\gamma_j}{b_i\gamma_i^2}Q + \frac{\sum_{j\neq i} b_j\gamma_j}{b_i^2\gamma_i^3}\pi_i\\ &\quad - \sum_{j\neq i}\frac{\sum_{k\neq i,j} b_k\gamma_k}{b_i\gamma_i^2 b_j\gamma_j}\pi_j,\end{aligned}$$

$$(11)\quad \begin{aligned}\frac{\partial q_i}{\partial \gamma_j} &= B - \frac{b_j}{b_i\gamma_i}Q - \frac{b_j}{b_i^2\gamma_i^2}\pi_i\\ &\quad - \frac{\sum_{k\neq i,j} b_k\gamma_k}{b_i\gamma_i b_j\gamma_j^2}\pi_j + \frac{b_j}{b_i\gamma_i b_k\gamma_k}\pi_k.\end{aligned}$$

where

$$A = -\frac{a_i\sum_{j\neq i} b_j\gamma_j}{b_i^2\gamma_i^2} + \sum_j \frac{a_j\sum_{k\neq i,j} b_k\gamma_k}{b_i\gamma_i^2(b_j)} \quad \text{and}$$

$$B = \frac{b_j}{b_i^2\gamma_i^2} - \sum_{k\neq i,j}\frac{b_j a_k}{b_k b_i\gamma_i^2}.$$

To be consistent with the characterization of consumer preferences portrayed above, the own (cross) quality adjusted first derivative should be greater (less) than zero. However, in reality the signs of the derivative represented in both Equations (10) and (11) may be ambiguous. That is, if one of the quality adjustment parameters is extremely low, then the own (cross) quality effect could be negative (positive). Even though both Equations (10) and (11) cannot globally show the clear impact of quality on market demand, both equations can be used to locally determine the empirical impact of quality on market demand by normalizing quality adjustment parameters and by using coefficients estimated by econometric methods, $\hat{a}_i$ and $\hat{b}_i$. Since we know actual market price and quantity of market consumption for each source-differentiated beef, we can determine the empirical signs of own and cross quality adjustment parameters in those equations. Equations (10) and (11) can also be used to simulate the impacts of quality on market demand across a variety of market sizes and market prices with Equation (9).

Simulation Results

In order to simulate the South Korean beef model, this study estimated coefficients, $\hat{a}_i$ and $\hat{b}_i$, using the same data set used in the previous section. Table 4 presents the statistical information of $\hat{a}_i$ and $\hat{b}_i$ all of which were statistically significant at the 1% level. The statistics showed that the signs of beef prices of South Korea, U.S., Canada, and New

Table 4. Statistical Information of Estimated Parameters, $\hat{a}$ and $\hat{b}$

	$\hat{a}_i$	S.E.	t-value	$\hat{b}_i$	S.E.	*t*-Value
q_{sk}	34.96206*	1.75002	19.98	−0.00034*	0.00004	−7.86
q_{us}	4.05512*	0.09721	41.72	−0.00005*	0.00001	−5.14
q_{au}	1.72164*	0.12643	13.62	0.00011*	0.00002	5.01
q_{ca}	3.35810*	0.12916	26.00	−0.00036*	0.00014	−2.52
q_{nz}	2.38724*	0.04387	54.41	−0.00003*	0.00001	−2.55

In order to estimate parameters, this study used system equation model because error terms are simultaneously correlated at time *t*.
* represents statistical significance at 1% level.

Zealand were negative as expected, while the beef price of Australia was positive. Following coefficient estimation, this study replaced $\hat{a}_i$ and $\hat{b}_i$ for a_i and b_i in Equations (10) and (11) to confirm the empirical change of sign in the own and cross quality adjusted first derivative equations.

Table 5 presents the results of the simulation of a change in quality on consumer demand for various beef products. Case 1 showed the

Table 5. Impacts of Quality Change with/without Changes in Market Size and Prices

Case 1: Impact of Quality Change/Market Size and Prices Held Constant

	$\hat{\gamma}_{sk}$	$\hat{\gamma}_{us}$	$\hat{\gamma}_{au}$	$\hat{\gamma}_{ca}$	$\hat{\gamma}_{nz}$
q_{sk}	+	−	+	−	−
q_{us}	−	+	+	−	−
q_{au}	+	+	−	+	+
q_{ca}	+	−	−	−	−
q_{nz}	−	−	+	+	+

Case 2: Impact of Quality Change and an Increase in Market Size

	$\hat{\gamma}_{sk}$	$\hat{\gamma}_{us}$	$\hat{\gamma}_{au}$	$\hat{\gamma}_{ca}$	$\hat{\gamma}_{nz}$
q_{sk}	+	−	+	−	−
q_{us}	−	+	+	−	−
q_{au}	+	+	−	+	+
q_{ca}	+	+*	−	−	+*
q_{nz}	−	−	+	+	+

Case 3: Impact of Quality Change and an Increase in Market Size and Prices

	$\hat{\gamma}_{sk}$	$\hat{\gamma}_{us}$	$\hat{\gamma}_{au}$	$\hat{\gamma}_{ca}$	$\hat{\gamma}_{nz}$
q_{sk}	+	−	+	+*	−
q_{us}	−	+	+	−	−
q_{au}	+	+	+*	−*	+
q_{ca}	+	+*	−	−	−
q_{nz}	−	−	+	−*	+

Case 4: Impact of Quality Change with an Increase in Market Size and Prices of Imported Beef and a Decrease in South Korean Beef Price

	$\hat{\gamma}_{sk}$	$\hat{\gamma}_{us}$	$\hat{\gamma}_{au}$	$\hat{\gamma}_{ca}$	$\hat{\gamma}_{nz}$
q_{sk}	+	−	+	+*	−
q_{us}	−	+	+	−	−
q_{au}	+	+	+*	+	+
q_{ca}	+	+*	−	−	−
q_{nz}	−	−	+	−*	+

$\hat{\gamma}_i$ is quality difference for beef *i* sourced from country *i*.

quality effect on market demand given market size with prices held constant. The empirical sign of the own quality effect was shown to be positive in South Korean, U.S., and New Zealand beef, while the sign was shown to be negative with respect to Australian and Canadian beef, implying through Equation (10) that the existing quality evaluation for South Korean, U.S., and New Zealand beef were relatively underestimated compared with those for Australian and Canadian beef.

The empirical sign of Equation (11), representing a cross quality effect, provides key information for understanding the impact that existing quality perceptions have on South Korean beef consumers. Note that two beef products can be quality substitutes; that is, a rise in the quality of one beef product leads to a decreased in demand for the other beef product. Or they can be quality complements; that is, a rise in the quality of one beef product leads to an increase in demand for the other beef product. For example, Australian beef was a quality substitute for South Korean beef demand, while U.S., Canadian, and New Zealand beef were quality complements for South Korean beef demand, implying by Equation (11) that the existing quality evaluation for Australian beef may be overestimated relative to those of the other foreign sourced beef, while the existing quality evaluation for U.S., Canadian, and New Zealand beef may be underestimated compared with that of Australian beef. For U.S. beef demand, Australian beef was a quality complement, but South Korean, Canadian, and New Zealand beef were quality substitutes.

Case 2 in Table 5 illustrates the impact of a similar evaluation of quality changes but also allows market size to change. When cases 1 and 2 are compared, an increase in market size did not affect own quality effects. However, notably cross quality effects were affected. That is, Canadian beef changed from a quality substitute for both U.S. and New Zealand beef in case 1, to a quality complement in case 2.

Case 3 in Table 5 shows the impact of simulating the effect changes on product quality on market demand where both market size and prices of imported beef are allowed to change. When comparing cases 1 and 3, an increase in market size and prices of imported beef influenced not only the own quality effect in Australian beef but also cross quality effects in South Korean, Australian, Canadian, and New Zealand beef demand. A simultaneous increase in market size and prices of imported beef transformed the own quality effect of Australian beef from negative to positive, implying, by Equation (10), that the relatively large quality impact for Australian beef may be adjusted to the level of those for other beef. Canadian and U.S. beef were changed from quality complement for South Korean beef demand and Canadian beef demand in case 1 to quality substitute in case 3, while Canadian beef was changed from quality complement for Australian beef demand and New Zealand beef demand in case 1 to quality substitute in case 3.

Case 4 in Table 5 shows the impact of simulating the effect changes on product quality on market demand where both market size and prices of both imported and locally produced beef are allowed to change. Except for the cross quality effect of Canadian beef on Australian beef demand, the results were the same as the results in case 3. The impact of a decrease in the price of South Korean beef had little effect in changing the empirical sign of market demand of either local or imported beef.

The above series of simulations serve several important uses. First, they show that there can be quality complementarity. That is, improvement in the quality of one beef product can actually increase the demand for another beef product. Without such analysis it may have been difficult to come up with an example of this phenomenon. Second, as a warning to economists and analysts who evaluate other markets, this simulation underscores that the impact of changes in product quality depends on other features of the market, such as market size and the overall level of prices. Not only did the magnitude of consumer response to quality changes vary with market size and the level of prices but even, in one instance, the direction of consumer response depended on these other market features.

Conclusion

Recognizing the importance of price and quality in the South Korean beef market, this study attempted to estimate price elasticities and to identify quality effects on market demand. The goal of the research was achieved through two different steps. In the first step, this study identified the conditions of the economic welfare function in which market participants maximized their economic benefit from trade. In the second step, this study analyzed quality effects on market demand of each source differentiated beef category using a quality adjusted demand system.

In undertaking these efforts, this study encountered some statistical obstacles in performing empirical estimation under the model. To solve the problems associated with biased and inconsistent estimators in the presence of misspecification errors while maintaining economic consistency of the model, this study respecified the model through (1) the elimination of extreme outliers, (2) arbitrarily resorting the data, and (3) using a weighted regression. Only when these steps were followed was it possible to produce a statistically valid model.

The empirical results showed that South Korean beef consumers are shown to be negative but not sensitive to changes in the own price of each source-differentiated beef product except for New Zealand beef. For South Korean beef, all four foreign sourced beef products were shown to be substitutes. In particular, U.S. beef exhibited the greatest degree of substitutability with South Korean beef. This study also found that, with increasing market size, Canadian beef and U.S. beef were shown to easily extend their South Korean market shares relative to other origin differentiated beef sources.

Related to quality effects, the results show that U.S. beef can extend its market share by increasing quality. In particular, this result explains why market demand for U.S. beef had decreased since December 2003 when a BSE outbreak in the U.S. was feared. Another finding was that an increase in the prices of foreign sourced beef and a decrease in the price of South Korean beef do not necessarily decrease market demand for the foreign sourced beef products.

[Received December 2007; Accepted August 2008.]

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Appendix 1. The parameter relationships between Equations (2) and (8) are explored below.

$$\text{(A1)}\qquad \alpha_{1i} = \frac{\sum\limits_{j\neq i} b_j a_i}{b_i^2} - \sum_{j\neq i}\left[\frac{\sum\limits_{j\neq i,k} b_j a_k}{b_k b_i}\right],$$

$$\text{(A2)}\qquad \alpha_{2i} = -\frac{\sum\limits_{j\neq i} b_j}{b_i},\quad \text{and}$$

$$\text{(A3)}\qquad \alpha_{3j} = \delta'\sum_{j\neq i}\left[\frac{\sum\limits_{j\neq i,k} b_j}{b_i b_k}\right] - \delta\sum_{j=i}\left[\frac{\sum\limits_{k\neq i} b_k}{b_i^2}\right],$$

where $\delta' = 1$ when $j \neq i$ and 0 otherwise and $\delta = 1$ when $j = i$ and 0 otherwise. To be consistent with the maximization hypothesis of the *EWF*, the second-order conditions of the *EWF* require that the Hessian matrix be negative semidefinite at the optimal point. This condition is expressed as $-\sum\limits_{j=i}\left[\sum_{k\neq i} b_k/b_i^2\right]$. Also, the Hessian matrix, $[\alpha_3]$, must satisfy homogeneity and symmetry conditions. The second order conditions for the multiple choice variable problem of the demand system are most easily expressed in terms of the matrix of the second derivative of the utility function. This matrix, known as the Hessian matrix, takes the form

$$H = \begin{pmatrix} u_{11} & u_{12} & u_{13} & u_{14} & u_{15} \\ u_{21} & u_{22} & u_{23} & u_{24} & u_{25} \\ u_{31} & u_{32} & u_{33} & u_{34} & u_{35} \\ u_{41} & u_{42} & u_{43} & u_{44} & u_{45} \\ u_{51} & 52 & u_{53} & u_{54} & u_{55} \end{pmatrix},$$

where $u_{ij} = \partial p_i/\partial q_j = \partial^2 u/(\partial q_i \partial q_j)$. The Hessian matrix in a maximization problem must be negative semidefinite. This means that for any vector (h_1,h_2,h_3,h_4,h_5), H must satisfy

$$(h_1,h_2,h_3,h_4,h_5)\begin{pmatrix} u_{11} & u_{12} & u_{13} & u_{14} & u_{15} \\ u_{21} & u_{22} & u_{23} & u_{24} & u_{25} \\ u_{31} & u_{32} & u_{33} & u_{34} & u_{35} \\ u_{41} & u_{42} & u_{43} & u_{44} & u_{45} \\ u_{51} & 52 & u_{53} & u_{54} & u_{55} \end{pmatrix} \times \begin{pmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \\ h_5 \end{pmatrix} \leq 0.$$

In order to satisfy the negative semidefinite of the Hessian matrix, the diagonals of Hessian matrix must be negative. With quality adjustment parameters defined for each source-differentiated beef product, the parameters, α, in Equation (8) are redefined as follows:

$$\text{(A4)}\qquad \alpha_{1i} = \frac{\sum\limits_{j\neq i} b_j\gamma_j a_i}{b_i^2\gamma_i} - \sum_{j\neq i}\left[\frac{\sum\limits_{j\neq i,k} b_j\gamma_j a_k}{b_k b_i\gamma_i}\right],$$

$$\text{(A5)}\qquad \alpha_{2i} = -\frac{\sum\limits_{j\neq i} b_j\gamma_j}{b_i\gamma_i},\quad \text{and}$$

$$\text{(A6)}\qquad \alpha_{3j} = \delta'\sum_{j\neq i}\left[\frac{\sum\limits_{j\neq i,k} b_j\gamma_j}{b_i\gamma_i b_k\gamma_k}\right] - \delta\sum_{j=i}\left[\frac{\sum\limits_{k\neq i} b_k\gamma_k}{b_i^2\gamma_i^2}\right],$$

where all $\gamma = 1$ indicates that all source differentiated beef are homogeneous in terms of quality. Then Equations (A4), (A5), and (A6) will be reduced to Equations (A1), (A2), and (A3), respectively.