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U.S. Meat Exports and Food Safety Information

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Abstract

New information about food safety can stimulate a sudden, significant concern by the public, resulting in a pronounced change in consumer demand. One such example is the declining level of beef consumption in Europe and Japan, stemming from the outbreak of Bovine Spongiform Encephalopathy (BSE), known as mad-cow disease. This study evaluates the impacts of the BSE outbreak in Japan in September 2001 on the import demands for U.S. meat in Japan and South Korea, using a nonparametric revealed preference approach. Empirical results show that there are excess violations in the Japanese data after the timing of the outbreak, but not in the South Korean data, implying that the event has influenced Japanese meat import demand, but not South Korean meat import demand.

Keywords: Bovine Spongiform Encephalopathy, meat import demand, revealed preference

Highlights

New information about food safety can stimulate a sudden, significant concern by the public, resulting in a pronounced change in consumer demand. One such example is the declining level of beef consumption in Europe and Japan, stemming from the outbreak of Bovine Spongiform Encephalopathy (BSE), known as mad-cow disease.

BSE was initially recognized in cattle in the United Kingdom in 1986. Within a thirteen-year period, from 1987 to 2000, the total number of infected cattle swelled to 180,000 in Europe. Consumers were suddenly alerted to the danger on March 20, 1996, when the U.K. government announced that there was a possible link between consumption of BSE-infected meat and the development of a new variant of its human equivalent, known as Creutzfeldt-Jacob disease. The release generated a substantial level of media attention and resulted in an immediate and significant decline in beef consumption in Europe.

In September 2001, the Japanese government reported the first case of BSE within the country. The case was the first idenfied outside of Europe. Consumption of beef in Japan fell sharply, and beef prices dropped significantly. The damage was compounded by the discovery of a second infected cow two months later. Third and fourth suspected cases were reported during the subsequent months, and the recurrent cases of BSE continued to fuel consumer concern and ravaged Japan's beef industry.

The objective of this study is to evaluate the impacts of the BSE outbreak in Japan on the demand for U.S. meat in Japan and South Korea. The two countries were selected because Japanese consumers have experienced a BSE outbreak in their country and South Korea is the closest country to Japan, albeit South Korean consumers have not experienced any outbreak of BSE. In addition, the two countries have been the most important importers of U.S. beef for the last decade.

Empirical results showed that there are excess violations of stable preference after September 2001 in the Japanese data, but not in the South Korean data. This suggests that the event has influenced Japanese meat import demand, but not South Korean meat import demand.

U.S. Meat Exports and Food Safety Information

Hyun J. Jin and Won W. Koo*

INTRODUCTION

New information about food safety can stimulate a sudden, significant concern by the public, resulting in a pronounced change in consumer demand. One such example is the declining level of beef consumption in Europe and Japan, stemming from the outbreak of Bovine Spongiform Encephalopathy (BSE), known as mad-cow disease.

BSE is a lethal, central nervous system disease which specifically targets cattle. The disease is characterized by the appearance of vacuoles, or clear holes in neurons in the brains of affected cattle. BSE was initially discovered in cattle in the United Kingdom in 1986, but reached epidemic proportions in Europe by 1992, with more than 1,000 reported cases. Within a thirteen-year period, from 1987 to 2000, the total number of infected cattle swelled to 180,000 in Europe.[1] Consumers were alerted to the danger March 20, 1996, when the U.K. government announced that there was a possible link between consumption of BSE-infected meat and the development of a new variant of its human equivalent, known as Creutzfeldt-Jacob disease. The release generated a substantial level of media attention and resulted in an immediate and significant decline in beef consumption in Europe. Consumers' concerns over the disease have continued to grow in European countries and around the world.

In September 2001, the Japanese government reported the first case of BSE within the country. The case was the first identified outside of Europe. The Japanese beef industry reeled under the combined reaction in its domestic and export markets. Many wholesalers and retailers suffered drops in sales ranging from 5% to 50%. Consumption of beef in Japan fell sharply, and beef prices dropped significantly.[2] The damage was compounded by the discovery of a second infected cow two months later. The second finding aggravated the situation and brought bigger shocks to the public. Third and fourth suspected cases were reported during the subsequent month, and the recurrent cases of BSE continued to fuel consumer concern and ravaged Japan's beef industry.

It has been reported in literature that consumers' responses to food safety information have significant consequences in the food production industry and international trade of agricultural and food products (e.g., Henson and Mazzocchi, 2002). Studies specifically

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[1] See, for example, the *Official BSE Homepage*, http://www.defra.gov.uk/animalh/bse/, provided by U.K. Department for Environment, Food, & Rural Affairs, London, the United Kingdom.

[2] More details about the outbreak of BSE and effects on the beef industry and consumers in Japan can be found, for example, in 1) *Ananova News*, September and October, 2001: http://www.ananova.com/news/?keywords=BSE,Farming,Japan,World, 2) *Japan Times*, September and October, 2001, http://www.japantimes.co.jp, and 3) *Mainichi Daily News* in Japan, September 2001, http://mdn.mainichi.co.jp/.

considering the BSE effects on consumers and producers include Ashworth and Mainland (1995); Latouche, Rainelli, and Vermersch (1998); Verbeke and Ward (2001); Henson and Mazzocchi (2002); and Pennings, Wansink, and Meulenberg (2002). Since BSE has mainly occurred in European countries, with the notable exception of Japan, studies of the BSE outbreak and consumers' responses have focused on the cases in Europe. An exception is the study by Jin and Koo (2003). They show that there is an ongoing structural change in Japanese consumers' preferences for meat; their tastes for meat have systematically moved away from beef to its substitutes, pork and chicken. This suggests consequential impacts of the BSE outbreak on the demand for imported beef in Japan.

The objective of this study is to evaluate the effects of the BSE outbreak in Japan on the demand for U.S. meat in two countries selected for comparison: Japan and South Korea. Japanese consumers have suffered a BSE outbreak in their country, but South Korean consumers have not. Pennings, Wansink, and Meulenberg (2002) argue that the relative influence of risk perception and risk attitude on consumers' reactions depends on the accuracy of knowing the probability of being exposed to the risk. Consumers in South Korea could believe that the probability of being exposed to BSE-infected beef might be smaller than that for Japanese consumers. Different perceptions of risk may lead to different reactions by consumers and therefore different evolution of the import demand for meat in the two countries.

Empirical results from the study of the two countries' demand for U.S. meat reveal some interesting results. First, since Japan has suffered the first case of BSE outside of Europe, and Korea is the closest country to Japan, consumers' responses in the countries can be compared to responses by consumers in European countries. Second, the two countries are leading beef-producing and -consuming countries in Asia. Therefore, their cases can form the basis for predicting other Asian countries' responses to a BSE outbreak or similar types of food safety issues. Third, this study provides valuable information for meat-exporting countries because Japan and South Korea are the primary importers of beef from major beef-exporting countries, such as the United States and Australia.[3] Since U.S. beef is known as BSE-free, this study could be used to evaluate whether the decreased Japanese beef consumption and structural change in consumer preference for meat are related solely to BSE-concerned domestic beef or also to imported BSE-free beef. If Japanese consumers consider beef from the BSE-free countries, mainly the United States and Australia,[4] as substitutes for their beef, the exporting countries may

[3] According to the Economic Research Service (ERS), the U.S. Department of Agriculture (USDA), during the last two decades Japan has been the largest export market for U.S. beef, typically importing at least twice as much U.S. beef as the second largest export market. The second-largest export market is South Korea, which is the fastest growing importer. During the last four years, imported beef averaged 66% and 52% of the total consumption in Japan and South Korea, respectively. The imported beef markets in Japan and South Korea are virtually monopolized by the United States and Australia. In recent years, the United States has increased exports of its chilled special cuts of grain-fed beef, an item in high demand in these countries. As a result, the United States now enjoys a slight lead over Australia as an exporter of beef to Japan and South Korea.

[4] For more information about the claim of BSE-free countries, see, for example, 1) *Ag Journal*, Country Roads Network, February 7, 2002: BSE in Japan Affect U.S. Producers, http://www.agjournalonline.com/, 2) U.S. Department of Agriculture, Food Safety and Inspection Service, November 30, 2001, *News Release: BSE Analysis by Harvard Center for Risk Analysis*, Release N. 024101, Washington D.C.

take advantage of the situation to increase their market shares. However, if the Japanese consumers' panic extends to any type of beef, whether domestically produced or imported, then this will have a detrimental effect on beef-exporting countries. This study also shows a consequential response in a neighboring, major beef-importing country, South Korea. Lastly, information from this study might be valuable for pork- or poultry-exporting countries because changes in meat import demand would imply decreased import demand for beef and, simultaneously, increased demand for its substitutes.

The remainder of the paper is organized as follows. The revealed preference test for structural change in market demand is reviewed in the second section. Data used in the study are detailed in the third section. The fourth section presents the procedure for empirical analysis. The fifth section displays empirical results of the tests in Japanese and South Korean demand for U.S. meat products. A summary and conclusion follow in the last section.

NONPARAMETRIC APPROACH FOR DEMAND ANALYSIS

In testing structural changes in market demand, the parametric approach has traditionally been used (e.g., Eales and Unnevehr, 1988; Heien and Wessells, 1988; Moschini and Meilke, 1989; and Choi and Sosin, 1990). The approach specifies a functional form of market demand and confirms a structural change by rejecting stability of parameter estimates or by accepting the difference between residuals of sub-samples at a conventional significance level.

We expect a structural break in the meat demands of Japan and South Korea at the time of the outbreak, September 2001, or the following month. From our sample data, we could obtain only 12 post-crisis observations. This would be considered too few to implement a parametric approach, and would result in a degree of freedom problem under a parametric approach. Therefore, this study adopts the nonparametric approach.

The revealed preference nonparametric method is an alternative to the traditional parametric approach. Previous applications of the nonparametric approach include Varian (1985); Swofford and Whitney (1986); Ashenfelter and Sullivan (1987); Chalfant and Alston (1988); Hildenbrand (1989); Alston and Chalfant (1991); Burton and Young (1991); Choi and Sosin (1992); Sakong and Hayes (1993); Gorny and Ahmadi-Esfahani (1993); Famulari (1995); and Frechette and Jin (2002).

The method does not require a specification of the demand system and uses an economic logic based on the Axiom of Revealed Preference. Under the Axiom, market demand is stable so that variation in observed quantities demanded can be explained by changes in relative prices or relative expenditures. If market demand is stable, market participants will not switch two bundles of goods that are affordable to them at different time points. Otherwise, the Axiom does not hold, and the alternative that there are shifts in market demand patterns is accepted.

Suppose there is a representative meat importer who has a stable set of well-behaved preferences. Assume that his demand for meat products is weakly separable from his demand for other commodities, and that his demand data have been generated by maximization of his utility function. Under the null hypothesis of well-behaved, weakly separable demands, there exists a

utility function U(.) that is nonsatiated, continuous, monotonic, and concave that rationalizes the data.

This study specifically uses a weak form of the Axiom called the WARP. According to the WARP, if a bundle *a* is directly revealed preferred (denoted *DRP*) to any other bundle *b*, then *b* should not be *DRP a*. The weak axiom is violated if one finds a pair of such consumption bundles that both *a DRP b* and *b DRP a*. This could occur only if indifference curves had shifted, given the maintained hypotheses. Thus, finding a WARP violation could be a sufficient condition for rejecting the stability of market demand.

The absence of any WARP violations suggests stable preferences. However, this does not necessarily guarantee intransitivity of preferences. We therefore need a further test, such as the Strong Axiom of Revealed Preference (SARP), to determine intransitivity of the demand system. Finding no violation of SARP can be a sufficient condition for accepting stability of market demand. The underlying logic of the SARP test is that if some different bundles *a*, *b*, and *c* together imply that *a* is revealed preferred (denoted *R*) to *b*, *b R c*, then *c* should not be *R a*. Note that *R* is a sequential relation of *DRP* so that *a DRP d*, *d DRP f*, and *f DRP b* means *a R b*, where *d* and *f* are other consumption bundles different from *a* and *b*. The SARP is violated if such intransitivity of the three bundles is found in the matrix **W**.

The first step of the WARP test is the establishment of the price and quantity matrixes, denoted by **P** and **Q**, respectively, for *n* goods observed for the sample period from time *1* to time *T*. The next step is the construction of a matrix, **W**, with elements $w_{st} = p_t q_s / p_t q_t$, where p_t and q_t denote price and quantity vectors at time $t \in [1,T]$. All elements below the diagonal, w_{st} ($s < t$), are checked against the opposing elements above the diagonal, w_{st} ($s > t$). If one could find a pair such that both are less than one, a violation of WARP is identified. Any such WARP violation is interpreted as evidence of changes in the market demand pattern between time *s* and time *t* under the null hypothesis.

DATA

Data in this study consist of monthly quantities and prices of U.S. beef, pork, and poultry imported by Japan and South Korea. The unit of quantity is metric tons, denoted by MT. Import prices of Japan and South Korea are denoted by 1,000 yen and won, respectively, per MT. The data start from January 1989 and end in September 2002. The total observations amount to 165. Import prices of the two countries are defined by applying the destination-specific export prices of U.S. meat products to real monthly Japanese and South Korean currency values against the U.S. dollar.

Import quantities and export prices are obtained from *Foreign Agricultural Trade of the United States (FATUS),* published by the Foreign Agricultural Service (FAS), the U.S. Department of Agriculture (USDA). The U.S. export prices are differentiated by each destination country. The nominal exchange rates are converted into real values using consumer price index deflators. The nominal exchange rates are obtained from the Economic Research Service (ERS) of the USDA. Details for traded meat (beef, pork, and poultry) are presented in

the Appendix. Descriptive statistics of the import data of Japan and South Korea for U.S. meat are displayed in Table 1.

Table 1. Descriptive Statistics:
Monthly Data from January 1989 to September 2002

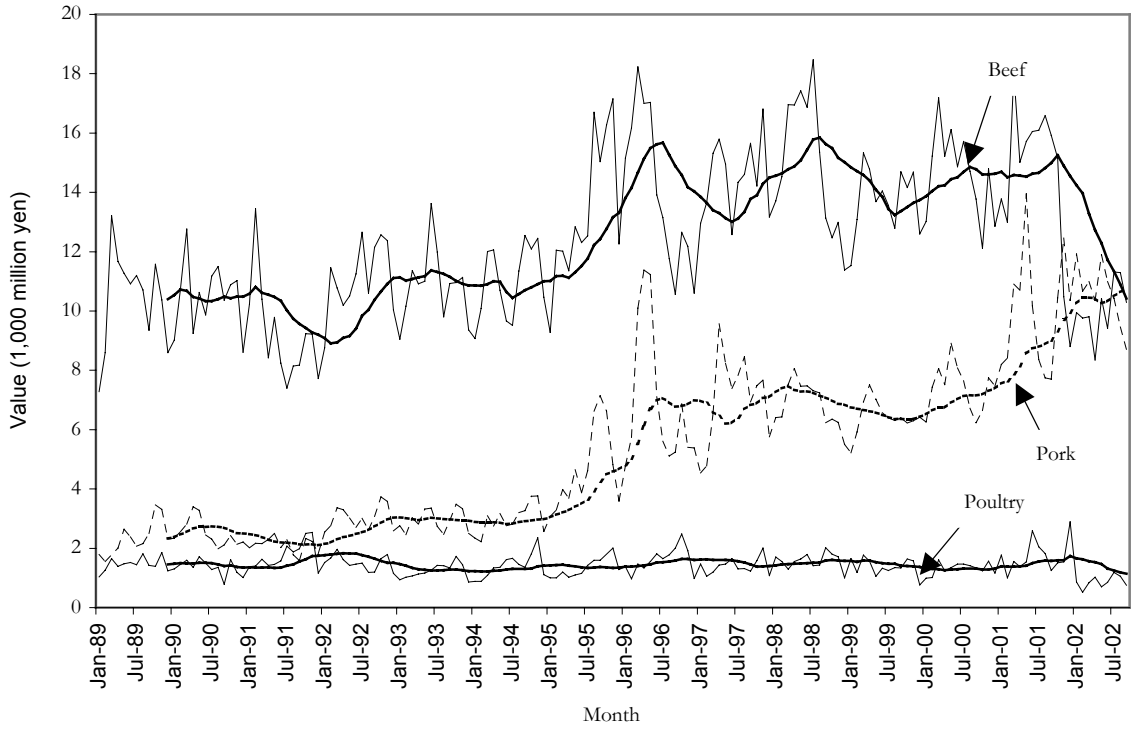
	Mean	Standard Deviation	Maximum	Minimum
Japan				
Price[a] of Beef	524.37	73.67	709.16	356.19
Price of Pork	496.08	83.60	770.01	362.89
Price of Poultry	153.81	26.27	284.88	102.77
Quantity[b] of Beef	24,217.94	6,296.20	35,910.70	11,315.00
Quantity of Pork	11,237.24	6,453.89	30,663.10	2,583.40
Quantity of Poultry	9,500.37	2,482.81	18,377.80	1,827.20
South Korea				
Price of Beef	3,167.74	502.44	5,601.49	1,681.30
Price of Pork	2,371.46	795.42	5,750.80	355.94
Price of Poultry	1,128.82	356.70	2,561.87	532.91
Quantity of Beef	6,658.66	4,498.07	20,322.30	137.30
Quantity of Pork	626.82	642.01	3,420.90	0.70
Quantity of Poultry	2,878.08	3,321.64	15,425.70	6.50

Note: [a] Prices are import prices for U.S. meat in Japan and South Korea, and they are denoted by local currencies. The units of the prices are 1,000 yen and 1,000 won per metric ton, respectively.
[b] Quantities are imported U.S. meat in Japan and South Korea, and the unit of quantity is metric tons.

The values of U.S. meats imported by Japan and South Korea are presented in Figures 1 and 2, respectively. Beef import by Japan had increased from December 1991 until March 1996. After March 1996, the time of the U.K. government's announcement, beef import fluctuated, and after September 2001, the month of the BSE outbreak in Japan, it decreased notably. This implies that the two events, the U.K. government announcement and the BSE outbreak in Japan, resulted in big shocks to the beef import demand in Japan.

It seems that pork imports have increased remarkably at the expense of beef, responding to the two events. After September 2001, there was a large increase in pork imports. This implies that some portion of Japanese import demand for U.S. meat has shifted from beef to pork.

Figure 1. The Values of Japanese Imports of U.S. Meats (1989-2002)



Note: Data are the values of meat (beef, pork, and poultry) imported by South Korea from the United States. The monthly data run from January 1988 through September 2002. The import quantities and export prices are obtained from the data set of *FATUS* of FAS of the USDA. A line of 12 months moving-average is constructed for each series and denoted by bold lines to show a long-term trend.

Unlike Japan, beef, pork, and poultry imports in South Korea have increased continuously. It seems that the two events did not result in significant shocks to the South Korean meat import demand.

The graphs themselves do not provide any reliable economic implication about preference changes. We need a systematic analysis that captures price and substitution effects on the demand behavior to derive any meaningful conclusion. The graph simply provides a rough idea that Japan could have been affected by the U.K. government announcement and BSE outbreak in the country and that South Korea may have not been affected by the two events.

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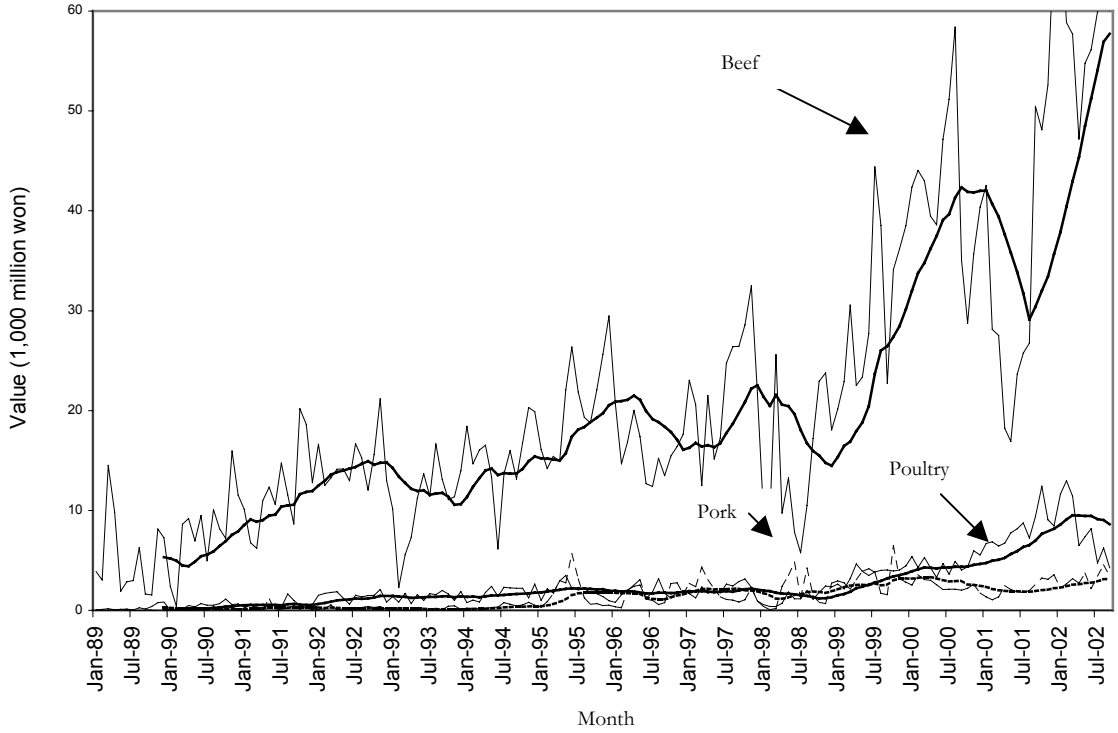
Figure 2. The Values of South Korean Imports of U.S. Meats (1989-2002)



Note: Data are the values of meat (beef, pork, and poultry) imported by South Korea from the United States. The monthly data run from January 1988 through September 2002. The import quantities and export prices are obtained from the data set of *FATUS* of FAS of the USDA. A line of 12 months moving-average is constructed for each series and denoted by bold lines to show a long-term trend.

CONTEXT OF EMPIRICAL ESTIMATION

This study analyzes the impacts of the BSE outbreak in Japan on the demands for U.S. meat in Japan and South Korea. The null hypothesis in this empirical test is that the import demands in Japan and South Korea are consistent with demand theory, i.e., stable so that variations in observed quantities demanded can be explained by changes in relative prices or relative expenditures. The null hypothesis implies that the BSE outbreak in Japan does not have any significant effects on meat import demands in the two countries. The alternative hypothesis is that the BSE outbreak in Japan has caused a systematic change in the Japanese and South Korean meat import demand, and there are therefore excess violations of WARP after September 2001.

The BSE outbreak may be the most significant factor that affects Japanese consumers' preference for meat during the sample period, but it may not have a significant effect on South Korean consumers' preference because they have not discovered BSE in their country. This is based on both local and international media and academic reports about the consumers' concerns following the BSE outbreak in Japan.[5] We expect different empirical results between Japan and

[5] See, for example, 1) *Japan Times* from September through October 2001, http://www.japantimes.co.jp, 2) *Hankyoreh News* in South Korea from September through December 2001, http://www.hani.co.kr, 3)

South Korea. Caswell and Mojduszka (1996) argue that without observing an outbreak in their own supply, consumers do not change their consumption patterns significantly. The study by Pennings et al. (2002) implies that the relative influence of risk perception and risk attitude on consumers' reactions depend on the accuracy of knowing the probability of being exposed to the risk. Combining the two views produces the following three consequential suppositions. First, consumers in South Korea believe that the probability of being exposed to BSE-infected beef is relatively lower than that in Japan. Second, Korean consumers therefore have different reactions toward beef domestically-produced and imported. Third, the meat import demand in South Korea evolves differently than that of Japan.

An important concern in the test for structural changes in the market demand is the nature of the alternative hypothesis. There may be a number of possible sources influencing meat demand. One needs to differentiate the effect of the BSE outbreak from the effects of other factors. To see clearly the BSE effect on meat trade, one needs to differentiate the effect of import price changes of meat products from other factors. Price change is the most important variable and significantly affects the demand for meat products through own-price and cross-price effects. The WARP test captures the price effects. However, in the international trade of an agricultural product, there exist other factors beyond the price change. These factors include changes in importing countries' real income levels, exchange rate effects, and third country effects. Thus, one needs to differentiate the three additional effects to derive a meaningful implication concerning the BSE effect on meat import demands.

The first factor, increases in an importing country's income level, can cause total real expenditure on meat consumption to increase through time. In this situation, each bundle of goods could be revealed preferred to all previous ones. If growth in real expenditure dwarfs variation in relative prices, it is likely that less will be revealed about the substitution relationship among goods than if total real expenditure remained relatively constant (Chalfant and Alston, 1988). This might hinder economists from rejecting the hypothesis of stable preference, even when in the presence of substantial changes in consumption choices, causing Type II error. Therefore, if we find no violations in the WARP test, Type II error can be a significant problem when there are income effects. In this case, a formal test for checking significance of the income effects is necessary. However, if we find enough violations to reject the null hypothesis and to support a maintained alternative hypothesis, the concern about the power of the nonparametric revealed preference test will not be significant.

Whether or not real expenditure for meat imports increased enough to make the test less powerful can be tested, using a method suggested by Chalfant and Alston (1988). Recall that the data were arranged chronologically, so that the first row in the matrix **W** relates to prices in period 1, the second to prices in period 2, and so on, while the columns involve observed quantities in the same way. When real expenditures rise through time, it is likely that the cost at any time t of buying bundles purchased earlier in the sample will be less than observed expenditures at time t. Similarly, the cost of bundles purchased later in the sample, when measured by prices at time t, is likely to exceed actual expenditures at time t. The extreme case occurs when all elements below the diagonal in **W**, w_{st} ($s < t$), are less than one and all elements

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CNN news, September 10, 2001: Japan Reports First Case of Mad Cow, http://www.cnn.com, 4) Jin, Sun, and Koo (2002), Working Paper in North Dakota State University.

above the diagonal, w_{st} ($s > t$), exceed one. This case occurs when all elements left of the diagonal are less than the diagonal elements for all rows and, at the same time, all elements right of the diagonal exceed the diagonal elements.

In this context, the number of occurrences of both $w_{st}(s < t) < 1$ and $w_{st}(s > t) < 1$ is checked to see the effects of real expenditure increase in the revealed preference test. If the number of elements that are less than one in the lower triangle is significantly larger than that in the upper triangle, it suggests that real expenditure in meat imports increased so that the power of the test is low. The same test can be performed to see the effects of real expenditure increase in a specific sample period using a sub-sample of the data.

The second factor, exchange rate effects, could cause a bias in the analysis if it is ignored because of the fact that import demand is also affected by the importing country's currency value against the exporting country's currency. This is especially true for meat trade between Asian countries and the United States because meat is traded in the exporter's currency, implying that importers face two cost components: meat export prices and exchange rates. Thus, in this study, we use meat price data denoted by local currencies by applying exchange rates between the importing countries and the United States to destination-specific U.S. meat export prices.

The third factor, the third country effect, can be significant in the analysis because although the United States is the most important meat-exporting country to Japan and South Korea, the two countries also import meat from other countries, such as Australia and Canada. Therefore, changes in other exporting countries' meat prices and exchange rates could cause changes in the demand for U.S. meat. This is the third country effect. A significant third country effect would make it invalid to assume a weakly separable meat group from other commodities because meat of another exporting country is not separable from the meat group in analysis. In this situation, the analysis of meat import demand might bear out a bias from the erroneous separability assumption.

The third country effect can be either a nonlinear or linear shock to meat import demand. If a third country effect is transitory, it can be considered a nonlinear shock. In this case, the effect may cause at best few excess WARP violations in the empirical analysis. This effect could be insignificant in the test if one specifies the acceptance region of the WARP test to be less than 100% consistency. On the other hand, if it is linear, then it will affect the market shares of U.S. meat in Japan and South Korea. This might cause a significant bias in interpretation of the results when the third country effects are not captured in the test because changed market shares could be a source for structural change in demand for meat, making acceptance of the alternative hypothesis less meaningful. Therefore, one needs to determine whether or not the market shares of U.S. beef in the importing countries have changed significantly.[6] If the market

[6] If a third country effect affects linearly and the shock comes from a third country's beef side, then the market share of U.S. beef in a destination market will be changed. Alternatively, if the third country shock comes from a third country's pork or poultry side, then it will affect the market share of U.S. pork or poultry and consequently that of U.S. beef. This will cause a change in the meat import demand. In these two cases, whether the third country shock is linear or nonlinear transitory can be identified by an analysis of the market share of U.S. beef. Although the third country shock affects the market share of U.S. pork or poultry, if the market share of U.S. beef is not consequently affected by the shock, the

share is constant in the long-term, then any third country effect can be considered a transitory nonlinear shock.

In the revealed preference approach, in addition to a linear shock, transitory nonlinear shocks may affect preferences, causing an apparent violation of the WARP even in the absence of systematic changes in the market demand (Frechette and Jin, 2002). Thus, a rejection of the Axioms can be triggered without systematic changes occurring in market demand, causing a Type I error. A nonlinear shock, for example, fad or transitory third country effect, may cause a WARP violation, which may lead economists to significant misinterpretation of the empirical results because there is no error term in the WARP test. Strictly speaking, even just one pair of observations violating WARP would have been sufficient to reject the null hypothesis of stable utility. Given possible measurement errors, erroneous assumptions, and nonlinear shocks, it seems unreasonable to specify the acceptance region of the test as 100% consistency with WARP. A violation of WARP can occur either because of non-optimizing behavior or because of measurement error in the data or transitory nonlinear shocks. An erroneous separability or aggregation assumption also could cause a WARP violation.[7] In addition, increasing the sample size does not affect the rejection criterion even though the potential number of violations rises exponentially with the number of observations (Famulari, 1995).

Therefore, if one or more shifts in the market demand are noted, then a socio-economic linear shock must be differentiated from other transitory nonlinear shocks or errors in model specification. The differentiation can be accomplished by verifying the timing and pattern of such shifts. If the frequency of violations is substantially high in a period that is synchronized with the timing of a socio-economic shock, then we can accept the alternative hypothesis that changes in the demand patterns are because of the socio-economic shock. This procedure should be based on the assumption that as long as the structure of utility is fixed over the sample, there exists an unconditional probability of observing a violation due to nonlinear shocks, measurement errors, or erroneous aggregation or separability assumption, and the probability is the same in each sub-period (with same time length) unless the structure of utility shifts systematically.

This paper proceeds by splitting the whole sample into three sections. The first section is the time block from the beginning of the sample to a month before the timing of U.K. government announcement, March 1996. The middle section is from March 1996 to a month before the timing of BSE outbreak in Japan, September 2001. The time period of the third

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market share of U.S. beef alone does not provide enough information for determining whether the shock is linear or transitory. However, in this case, there is no change in preference from beef to its substitute or in the opposite direction. One can only observe that real expenditure on meat imports increases.

[7] Following the WARP specification in the second section, the empirical test implicitly assumes a representative meat importer in Japan and South Korea, respectively, and his demand for meat is weakly separable from his demand for other commodities. However, if aggregation bias exists or a relevant good is excluded, the aggregate demand could appear unstable, even when individual preferences are stable. A separability or aggregation bias can cause an excess violation in the WARP test. However, the bias from the erroneous separability or aggregation assumption could not be significantly influential to economic interpretations of the results if one relaxes the acceptance region of the test to be less than 100% consistency.

section is from September 2001 to the last observation of the sample. When a WARP violation is observed, the expected probability of noting an observation in each section related to the violation is calculated by dividing the number of months in each section by the total number of months. This derivation is based on the assumption that when we observe a WARP violation the unconditional probability of observing the violation due to non-systematic factors, such as nonlinear shocks, measurement errors, or erroneous aggregation or separability assumption, is the same in each month unless the structure of utility shifts systematically. The realized probability is obtained from the results of the WARP test by dividing the number of observations involved in the WARP violations in each section with total number of observations involved in the violations. As the last step, the two probabilities are compared.

An example of interpretation of the comparison is as follows: within this specification, if the actual probability is significantly larger than the expected probability in the third section, then it can be interpreted as an indication that the BSE outbreak in Japan has caused systematic violations of WARP in the meat import demand in Japan or South Korea. That is, it can be considered that the reduced loyalty toward U.S. beef in Japan is due to the BSE outbreak in Japan. Another example is that if the actual probability is not larger than expected probability in the third section, it implies that there are no significant effects of the event on the two countries' meat import demand.

ESTIMATION AND RESULTS

A matrix is constructed from a product of the price matrix, $\mathbf{P}$, and the transpose of quantity matrix, $\mathbf{Q}^T$. The dimension of $\mathbf{P}$ is 165×3, and that of $\mathbf{Q}$ is 165×3. Thus, the dimension of the product matrix, $\mathbf{P}\cdot\mathbf{Q}^T$, is 165×165. The first row gives the costs of buying the 165 different bundles at January 1989 prices; the second row, the costs of the same bundles at February 1989 prices; and so on. The matrix, $\mathbf{W}$, described in the second section is constructed by dividing all elements of the matrix of $\mathbf{P}\cdot\mathbf{Q}^T$ with diagonal elements. All elements below the diagonal, w_{st} ($s < t$), are checked against the opposing elements above the diagonal, w_{st} ($s > t$). Let both elements be equal to two if both of the pair are less than one, which indicates violation of WARP; otherwise, equal to zero.

Under the null hypothesis of the WARP test, all observed choices are consistent with maximization of the same utility function of the representative importer. Note that the null hypothesis of the WARP test is that there is a representative meat importer who has a stable set of well-behaved preferences and his demand for meat is weakly separable from other goods. In other words, the import demands in Japan and South Korea are consistent with demand theory, i.e., stable so that variation in observed quantities demanded can be explained by changes in relative prices or relative expenditures. Any WARP violation is interpreted as evidence of changes in the market demand between time s and time t. Suppose that the null hypothesis is rejected; it then suggests that there has been at least a switch from beef to pork or poultry, and that the switch is not because of changes in relative prices or relative expenditures, but because of transitory or linear shocks.

The results of the WARP test for the sample data of the two countries are displayed in Table 2. It shows that there are 32 pairs of violations, switches in market demand, out of 13,530

total comparable pairs in the Japanese data, and 35 pairs of violations out of 13,530 total comparable pairs in the South Korean data. The violations suggest rejection of the null hypothesis of stable preference in the Japanese and South Korean data. Among the violation pairs, some may be due to switches of preferences caused by a linear shock, stemming from the BSE outbreak in Japan, and others may be due to transitory nonlinear shocks, measurement errors, or erroneous assumptions in the test.

Table 2. Results of WARP Test with the Japanese and South Korean Data

			Comparison of Three Sections			
			Sub-Period	P^e [c]	Number of Observations involved in Violation	P^r [d]
Japan	Total Comparable Pairs[a]:	13,530	First Section: (Jan. 1989 - Feb. 1996)	0.522	21	0.3281
	Pairs of Total Violation:	32	Second Section: (March 1996 - August 2001)	0.4	26	0.4063
	Probability of Violation[b]:	0.0023	Third Section: (After Sep. 2001)	0.078	17	0.2656
			Total	1.0	64	1.0
South Korea	Total Comparable Pairs:	13,530	First Section: (Jan. 1989 - Feb. 1996)	0.522	39	0.5571
	Pairs of Total Violation:	35	Second Section: (March 1996 - August 2001)	0.4	29	0.4143
	Probability of Violation:	0.0025	Third Section: (After Sep. 2001)	0.078	2	0.0286
			Total:	1.0	70	1.0

Note: [a] Total comparable pairs is calculated from 1) a product of 165 by 165, 2) subtracted by the number of diagonal elements, and 3) divided by two.
[b] Probability of violation is calculated from dividing total violation pairs by total comparable pairs.
[c] P^e denotes expected probability of finding observations involved in the WARP violation.
[d] P^r denotes realized probability of finding observations involved in the WARP violation.

Therefore, to derive meaningful implications related to the BSE outbreak in Japan from the noted WARP violation pairs, one needs to check the timing and frequency of the violation pairs before and after the event. Each country's whole sample is divided into three sections. Expected and realized probabilities of noting observations involved in the WARP violations which occurred are now calculated for each section, as described above. Let the expected probability of noting such observations be P^e and the realized probability P^r. P^e is 0.522, 0.4, and 0.078, respectively, for the first, second, and third section in both cases of Japan and South Korea. The actual number of observations involved in the violation pairs is 64 in the case of Japan and 70 in the case of South Korea. Note that each violation pair has two observations because a violation is identified from the comparison of the two elements in the WARP matrix. In each sub-section, the number of observations involved in the violation pairs is 21, 26, and 17, respectively, for the first, second, and third section in the Japanese data and 39, 29, and 2 in the South Korean data. Finally, the actual probability, P^r, is 0.3281, 0.4063, and 0.2656, respectively, for the first, second, and third section in the Japanese data and 0.5571, 0.4143, and 0.0286 in the South Korean data.

The results for the Japanese data show that the realized probability, P^r, is obviously larger than the expected probability, P^e, in the third section. Compared to this, in the first section, P^r is smaller than P^e, and in the middle section, both are similar. This suggests that there is a significantly larger number of violations after the BSE outbreak in Japan. For the South Korean data, P^r is smaller than P^e in the third section, and both are similar in the first and middle sections. This suggests that the BSE outbreak in Japan has not caused shifts in the meat import demand in South Korea. The results support the maintained alternative hypothesis in the case of Japan, but not in the case of South Korea.

Since there are no excess violations in the South Korean data after September 2001, although we reject the null hypothesis of stable preferences, we cannot accept the alternative hypothesis as long as the probability of noting violations due to transitory shocks, measurement errors, or erroneous model assumption is the same for each month. Note that the maintained alternative hypothesis in this paper is that the BSE outbreak in Japan has caused a systematic violation in the Japanese and South Korean data and there are, therefore, excess violations of WARP after September 2001. Although we could not perform any formal test to verify statistical significance of the difference between expected probability and realized probability in the three time sections, the results do not imply that the economic interpretation proposed in this section is questionable.

In the case of South Korean data, we could not accept the alternative hypothesis, and this may be partly due to the low power of the test caused by increased real expenditures on meat imports. Figure 2 suggests that real expenditures have increased. Without the effects of real expenditure increases, we may have observed enough violations to accept the alternative hypothesis.

A test to determine whether or not real expenditures on meat imports increased enough to make the test less powerful is performed by checking the number of occurrences in both

$w_{st}(s < t) < 1$ and $w_{ts}(s > t) < 1$. Note that there are 27,060 elements, except for the diagonal elements, in the matrix **W** for both countries. The results in the Japanese data show that in the

lower triangle, the number of elements that are less than one is 10,777 and in the upper triangle, the number is 2,681; while these figures are 11,303 in the lower triangle and 2,136 in the upper triangle in the South Korean data. The ratio of the number in the lower triangle against the number in the upper triangle is 4.01 and 5.29, respectively, in the Japanese and South Korean data. The ratios are larger than those from Martin and Porter's Australian meat consumption data in the study by Chalfant and Alston (1988), in which the ratio was 1.92, but they are smaller than that from Wohlgenant's U.S. meat consumption data in the same study, in which the ratio was 7.96. The ratios from the Japanese and South Korean data are relatively high, suggesting that real expenditure in meat imports in the whole sample period increased so that the power of the test is relatively low.

The number of occurrences of $w_{st} < 1$ is checked again for a sub-sample from September 2001 through the last observation to determine whether or not real expenditure after September 2001 increased enough to dwindle the effects of meat preference changes. The results show that the ratio is 2.03 for the South Korean data, which is significantly smaller than that for the whole sample and close to the Australian data in Chalfant and Alston's study. This suggests that the increase in real expenditure is much smaller in the sub-sample after September 2001, so concerns over the power of the test need not be great in the South Korean data. In the Japanese data, the ratio is 0.79, implying that the real expenditure in the import of U.S. meat has not increased after September 2001 but may have decreased. This implies that the interpretation of the results of the WARP test is robust to income effects in the Japanese data.

Chalfant and Alston pointed out that even when the power is low in nonparametric tests, relative to some desired level, it does not necessarily mean that the parametric approach should be adopted instead. They raised two supporting points for the argument. First, the same concerns over the nature of the data set would also affect the parametric approach. In a parametric analysis, Engel curves may explain more of variation in quantities consumed than substitution between goods does, just as with the nonparametric approach. Second, when a particular form for the demand system is estimated, the test for stable preferences is replaced by a test for stable preferences of a specific functional form, such as translog or almost ideal demand system. It is well-known that an arbitrarily chosen demand system may perform poorly as an approximation of the mechanism by which the data were generated (e.g., Deaton, 1986). Rejection of a hypothesis such as stability or homogeneity could then be due to use of the wrong functional form rather than a rejection of the economic proposition.

In the case of the Japanese data, the empirical results show that there are excess violations after September 2001. This suggests that due to the BSE outbreak there is a systematic change in meat import demand. Figure 1 implies relatively decreased import demand for beef and increased import demand for pork. However, to support the alternative hypothesis, one needs to analyze market shares of U.S. beef in Japan to determine whether third country effects are transitory or linear, because interpretation of the results in Table 2 is based on the assumption that any third country effects are transitory. If third country effects linearly affect import demand in Japan, differentiation between the BSE outbreak shock and third country effects is necessary before concluding that the BSE outbreak had any effect on Japanese demand for U.S. meat. Note that for the South Korean data, analyzing the U.S. meat market share is not necessary because the alternative hypothesis was not accepted, meaning that neither the BSE

outbreak nor a linear third country effect caused a systematic change in meat demand in the country after September 2001.

From the databases of *Production, Supply, and Distribution* by ERS and *FATUS* by FAS, the annual market share of U.S. beef in Japan is calculated by dividing the Japanese import of U.S. beef by the Japanese total beef import from 1989 through 2002. The average of the market share is 0.372 with the standard deviation 0.0298. The market share of 1989 was extraordinarily higher than the sample average; if we delete the value for 1989, then the average market share is 0.359 with the standard deviation 0.0143. The low standard deviation suggests that the long-term market share has been constant, implying that any third country effects on the Japanese import demand for U.S. beef can be considered transitory, and therefore supporting our conclusion.

The study by Jin and Koo (2003) shows that there is a structural change in the meat demand of Japanese consumers, from beef to its substitutes, and the timing of such structural change is synchronized with the month (October 2001) following the BSE outbreak in Japan. This is a complementary finding which supports the alternative hypothesis for the Japanese data because a change in the retail level will cause a change in import demand.

Imported beef has accounted for about 66% of the total beef consumption in Japan during last four years. The effect of the BSE outbreak was an immediate, sharp drop in Japanese consumption of both domestic and imported beef. Japanese consumers have significantly reduced beef consumption and increased pork and chicken consumption (*Japan Statistical Yearbook 2002*). Consumers' preferences may hinge on further discoveries of infected cattle and acceptance of BSE-free beef from the United States or Australia as a substitute for their domestic beef, called Wagyu. BSE concerns of Japanese consumers and their response to imported beef could play prominent roles in determining imports of U.S. meat in coming years.

Figures 1 and 2 suggest a seasonal pattern in the Japanese and South Korean data. It implies that the validity of the WARP test should be based on the robustness of the results to seasonality. The revealed preference test is meant to be invariant to seasonality (Frechette and Jin, 2002). Although seasonality does not represent a structural change, it may alter the frequency of inter-seasonal rejections of the WARP test compared to intra-seasonal rejections. Rejections of WARP can be due to seasonal changes in the structure of consumer preferences. This study evaluated the robustness of the revealed preference test to seasonal variation by checking whether or not seasonality caused excess violations of WARP.

This test was conducted as follows. The WARP matrix, **W**, was grouped into two sets by season (within season and across season) and the percentages of violations in the two sets were calculated. If seasonality were a problem in the revealed preference tests, one would expect that the frequency of violations across season must be larger than that within season. For a concrete inference, a test was performed to see whether the two sets of violation percentages were statistically different or not, using the Wilcoxon rank sum test in the one-way nonparametric analysis of SAS. The null hypothesis of no difference between the two groups' WARP violation frequency was not rejected at the 5% significance level. The average percentage of violations of the within-season set and that of the across-season set was not statistically distinguishable in

either the Japanese or South Korean data. This suggests no statistical evidence of excess violations of WARP caused by seasonality.

CONCLUSION

The objective of this study is to evaluate the impacts of the BSE outbreak in Japan on the demand for U.S. meat in Japan and South Korea. The two countries were selected because Japanese consumers have experienced a BSE outbreak in their country and South Korea is the closest to Japan, albeit South Korean consumers have not experienced a BSE outbreak. In addition, Japan and South Korea have been the most important importers of U.S. beef for the last decade. Empirical results showed excess violations after September 2001 in the Japanese data, but not in the South Korean data, suggesting that the event has influenced Japanese meat import demand, but not South Korean meat import demand.

The results from the Japanese and South Korean data provides important implications for meat-exporting countries because the two countries are the primary importers of beef from major beef-exporting countries, such as the United States and Australia. Even if U.S. beef is known as BSE-free, the results of this study indicate that structural change in Japanese consumers' preferences for meat due to the BSE crisis has caused a reduction in their demand for both domestic and imported BSE-free beef, while U.S. beef export performance has not dwindled in South Korea.

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Appendix

Description of Beef, Pork, and Poultry Exported from the United States to Japan and South Korea.

Meat	Export Commodities	10-Digit HS Code[a]
Beef	Beef and Veal - Fresh or Frozen Beef - Prepared or Preserved	201100010, 201100090, 201203000, 201203550, 201206000, 201303000, 201303550, 201306000, 202100010, 202100090, 202203000, 202203550, 202206000, 202303000, 202303550, 202306000, 210200000, 1602509020, 1602509500
Pork	Pork - Fresh or Frozen Pork - Prepared or Preserved	203110000, 203121000, 203129000, 203192000, 203194000, 203210000, 203221000, 203229000, 203292000, 203294000, 210110000, 210120020, 210120040, 210190000, 1602411000, 1602412000, 1602419000, 1602422000, 1602424000, 1602492000, 1602494000, 1602497000
Poultry	Poultry - Live Baby chicks Other live poultry Poultry Meats Chickens - Fresh or Frozen Turkeys - Fresh or Frozen Other poultry - Fresh or Frozen Poultry meats – Prepared or Preserved	207104020, 207104040, 207110020, 207110040, 207120020, 207120040, 207130000, 207140000, 207140010, 207140025, 207140030, 207140050, 207140090, 207210020, 207210040, 207390020, 207410000, 207102000, 207220000, 207240000, 207250000, 207260000, 207270000, 207270010, 207270025, 207270030, 207270045, 207270050, 207270090, 207390040, 207420000, 207104060, 207230000, 207310000, 207320000, 207330000, 207340000, 207350000, 207360000, 207390060, 207430000, 207500000, 1601000010, 1601000020, 1602310020, 1602310030, 1602310040, 1602310050, 1602310090, 1602320020, 1602320035, 1602320040, 1602320050, 1602320090, 1602390020, 1602390025, 1602390040, 1602390045

Note: HS Code is Harmonization Code System supported by World Customs Organization (WCO)