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This Paper is for the Annual Meeting of the American Agricultural Economics Association in Montreal, Quebec, July 27-30, 2003.

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The Effect of Food-Safety Related Information on Consumers' Preference: The Case of BSE Outbreak in Japan

Abstract: This study analyzes consumers' responses to food-safety related information by evaluating if Japanese consumers have undergone a structural change in their preferences for meat due to the BSE outbreak in the country. The axiom of revealed preference is utilized to test the stability of preference in Japanese meat consumption. The matrix of weak form of revealed preference (WARP) is partitioned and Kruskal-Wallis statistics are derived to evaluate whether the switches of preference are transitory or due to a structural change. Empirical results show that Japanese meat demand has undergone a structural change, synchronized with the BSE outbreak in Japan in mid-September 2001.

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Introduction

Food safety is an important issue for consumers today. In addition to the traditional socio-economic factors influencing consumers' choice, such as income level, product prices, and lifestyle, food safety significantly affects buyers' preference (Caswell, 1998; and Henson and Northen, 1998). Previous studies have examined the impact of food safety information on consumer demand and the consequent implications for the welfares of consumers and producers. For example, Foster and Just (1989) analyzed the impact of the milk contamination with Heptachlor in Hawaii during 1982. Brown and Schrader (1990) measured the impact of cholesterol in shell eggs on consumer demand. The results of these studies suggest that the food-safety issue is an important factor in consumers' demand for food.

New information about the safety of an agricultural product can stimulate a sudden upheaval of public concern, resulting in pronounced reduction in demand for the product. Consumers' responses to food safety information can have potentially significant consequences within the food production industry and the international trade of agricultural and food products. If a food safety-related panic creates an interim or long-term upheaval in purchasing patterns for a certain food, it could result in a shift in market demand for the food. Current concern over the declining level of beef consumption in Europe and East Asia, stemming from the outbreak of Bovine Spongiform Encephalopathy (BSE), known as mad-cow disease, provides a good case study for changes in consumer demand due to food safety information.

BSE has mainly occurred in European countries, except for Japan, and therefore, studies for the BSE outbreak and consumers' responses have focused on the cases in Europe. Ashworth and Mainland (1995) reviewed economic consequences of the BSE outbreak for the British meat industry. Latouche, Rainelli, and Vermersch (1998) conducted a survey study using a contingent valuation method to analyze consumer behavior in the area of Rennes after the BSE crisis. Their survey revealed that consumers are waiting for a greater transparency and that they would accept to pay for it. Verbeke and Ward (2001) investigated fresh meat consumption in Belgium during the period from 1995 through 1998 using an almost ideal demand system (AIDS). In specifying the demand system, they incorporated a media index mainly pertaining to BSE; their results showed that television publicity has a negative impact on beef expenditure, in favor of pork. Adda (2002) investigated the effects of past consumption of risky goods on current consumption patterns, using the "mad cow" crisis as a natural experiment. He found that new health information interacts with prior exposure to risks. Consumers with intermediate levels of past consumption decreased their demand for beef and sought higher quality products; while low and high stock consumers did not alter their behavior after the crisis. For the issue of consumers' preferences after the BSE outbreak, Mangen and Burrell (2001) investigated a structural change in Dutch consumers' preferences for meat and fish, responding to the U.K. government's announcement.[1] They used a switching AIDS model and a sample period that covers January 1994 through May 1998. The hypothesis of constancy of the parameters of the AIDS model for meat and fish was rejected against a more general time-varying parameter model. The combined effects of the underlying trends and the irreversible components of the BSE effect were against beef, minced meat, and meat products, and in favor of pork, prepared meat, poultry and fish.

The objective of this study is to test consumers' responses to food safety related information by evaluating if Japanese consumers' preferences for meat have undergone a structural change due to the BSE outbreak in the country. The results from this study add another layer of findings about consumers' responses to the BSE outbreak and add another empirical study toward food safety issue. The results of this study might contain important information for beef-exporting countries as well as for the Japanese government, beef producers, and processors. Two nonparametric tests are adopted in this paper. One is the weak axiom of revealed preference (WARP) test and the other is a test created by Frechette and Jin (2002), which will be explained in the third section. The tests utilize an economic logic invoked in the axioms of revealed preference, established by Samuelson (1938); Houthakker (1950); Afriat (1967); and Varian (1982, 1983).

Japanese consumers are chosen because of the following three reasons. First, Japan is the primary importer of beef from major beef-exporting countries, such as the United States and Australia.[2] Second, Japan is a leading beef-producing and -consuming country in Asia, and their response can be a basis for the prediction of consumers' responses in other Asian countries to a BSE outbreak or similar types of food safety issues. Finally, Japan has suffered the first case of BSE outside of Europe. Thus, their response can be compared or contrasted with European consumers' response.

This study tests whether a shift in consumers' preferences for meat occurred at all and, if it did, identifies the timing of such a shift. Figure 1 shows a gradual decrease in beef consumption from 1996 and then a sudden, large decrease around September 2001. Therefore, this study implicitly assumes that Japanese consumers had been gradually affected by the BSE outbreak in Europe and the U.K. government's announcement, and that they were affected most significantly by the outbreak in their own country. We expect that the most likely structural break point coincides with the timing of the BSE outbreak in Japan in September 2001 rather than the time of the U.K. government's release in March 1996. The pattern of preference change is likely to show that consumers may have switched meat consumption from beef to pork or chicken because there was no scientific evidence to suggest that the suspect bone and meat meal feedstuffs caused BSE-style reactions in pigs and chickens.

The remainder of the paper is organized as follows. A brief review of the BSE outbreak in Japan is contained in the second section. The nonparametric tests for stability and structural change in consumers' preferences are explained in the third section. Data used in the study are detailed in the subsequent section. The separability test between meat and fish is performed and the results are presented in the fifth section. The sixth section presents empirical results of the tests for stability and structural change in Japanese consumers' preferences for meat. A summary and conclusion follows in the last section.

A Brief Review of BSE Outbreak in Japan

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, that give the brain the appearance of a sponge or spongiform. BSE was initially recognized in cattle in the United Kingdom in 1986. The occurrence of BSE in cattle reached epidemic proportions in Europe by 1992, with more than 1,000 reported cases. Within the thirteen-year period, from 1987 to 2000, the total number of infected cattle swelled to 180,000 in the United Kingdom, Ireland, Portugal, France, and Switzerland.[3] Consumers' alert to the danger was further augmented by the U.K. government's announcement on March 20, 1996. The pronouncement of the finding generated considerable media attention and resulted in an immediate and significant decline in beef consumption. Consumers' concerns over the disease have grown around the world as well as in European countries. Authorities in European countries have banned suspect animal feed and launched offensives against fears of BSE-infected meat. But it has been difficult to assuage consumer panic. Beef sales in Europe plummeted after the news. Some governments outside Europe have banned importing beef from European countries.

After the 1996 announcement, beef consumption in Japan began to decline, and, at the same time, Japan's economic growth was slowing down. The news released by the U.K. government may not have not had a big impact on Japanese consumers because beef consumption in Japan comes mostly from domestic production and imports from BSE-free countries, such as the United States and Australia.[4] Without observing an outbreak in their own supply, consumers may not change their consumption patterns significantly (Caswell and Mojduszka, 1996). Moreover, Japan imported a negligible portion of beef from European countries. Therefore, Japanese consumers' responses to the U.K. government's release may have been gradual rather than pronounced.

Amid signs of the spreading of BSE and its human equivalent, known as Creutzfeldt-Jacob disease (vCJD), across Europe, Japan has tried to prevent the diseases from entering its borders. The Japanese government banned E.U. beef, food made from processed beef, and bull sperm that is used for breeding, and they restricted blood donations from people who have lived in Britain. However, on September 10, 2001, the Japanese government reported the first case of BSE within the country. The cow believed to carry the disease was a five-year-old Holstein and was located in Chiba Prefecture, which borders Tokyo on the east. The case was the first outside of Europe as well as the first in Asia. The Japanese beef industry reeled under the combined reaction in its domestic and export markets. South Korea and Singapore announced that they would stop imports of Japanese beef. China, Malaysia, and the Philippines joined the growing list of countries banning Japanese beef.

Strict European standards were adopted by the Japanese government and one million cattle were tested in an effort to fight the spread of the disease. At the same time, officials scrambled to reassure Japanese consumers and to persuade other countries to drop bans imposed on its meat after the announcement. Despite these measures, worries over food safety have taken a toll on the country's meat industry. Many wholesalers and retailers have suffered drops in sales ranging from 5 to 50 percent due to the concern over BSE. Consumption of beef in Japan has fallen sharply, and beef prices have dropped significantly.[5] During the period from 1998 through 2001, about 66% of beef sold in Japan was imported, and most imports came from the United Stated and Australia where they have not yet found any BSE. However, according to *International Agricultural Trade Report* (February 2002) by Foreign Agricultural Service of USDA, nearly 60% of Japanese consumers have stopped eating beef since the first case of BSE was reported. This may be partly due to a Japanese meat company blaming for imported beef as the source of the infected meat, which might further shake consumer confidence.

The damage was compounded by the discovery of a second infected cow two months later. On November 2001, Japanese authorities found a second cow suspected of having BSE in Hokkaido. The second finding aggravated the situation and brought bigger shocks to the public. Third and fourth suspected cases were reported during the next month, and the recurrent cases of BSE continued to fuel consumer concern and ravaged Japan's beef industry.

Context of Nonparametric Revealed Preference Test

This article focuses on testing whether Japanese market demands for meats have been unstable due to the country's BSE outbreak, which might cause a structural change in consumers' preferences. There are, broadly speaking, two different approaches in testing structural changes in market demand. The first approach chooses a functional form of market demand and utilizes a Chow-type test, random coefficients, or explicit demand shifters on the specified demand system. For a random coefficient approach, see, e.g., Chavas (1983) and Tegene (1990); for a demand shifter approach, refer, e.g., Burton and Young (1996); Kinnucan et al. (1997); and Burton, Young, and Cromb (1999). A structural change is implicated when stability of parameter estimates is rejected in a conventional significance level, when the difference between residuals of sub-samples is statistically and economically acceptable, or when a trend is statistically significant. This approach provides the economic significance and implications of a structural change.

The second approach is a nonparametric method which does not require a specification of the demand system. It uses an economic logic based on the Axioms of Revealed Preference. Under the Axiom, consumers' preferences are stable so that variation in observed quantities consumed can be explained by changes in relative prices or expenditures. If their preferences are stable, consumers will not switch two bundles of goods that are affordable to them at different time points. Otherwise, the Axiom does not hold. In this case, the null hypothesis of a well-behaved utility function is rejected, and structural change can be accepted.

We expect that Japanese consumers were most significantly affected by the BSE outbreak in their own country. Accordingly, the structural break point in the Japanese consumers' demand for meat might be the timing of the outbreak, September 2001, or the following month. From our sample data, we could get only 8 post-crisis observations. This would be considered too few to implement one of the parametric approaches described above, as using a parametric approach would lead to a degree of freedom problem. For this reason, this study adopts the nonparametric approach. Previous applications of the nonparametric test include Varian (1985); Swofford and Whitney (1986); Chalfant and Alston (1988); Hildenbrand (1989); Burton and Young (1991); Choi and Sosin (1992); Famulari (1995); and Frechette and Jin (2002).

The null hypothesis of the revealed preference test is that observed data confirm the restrictions implied by the maintained hypotheses of a stable set of well-behaved preferences and weak separability of the meat group from other commodities, and by the assumption that the data have been generated by maximization of a utility function of a representative consumer. Under the null hypothesis of well-behaved, weakly separable per-household 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 it is not the case that *b 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.

The WARP test begins by establishing the price and quantity matrixes, denoted by **P** and **Q**, respectively, for k goods observed for the sample period from time 1 to time τ. 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 $t \in [1, \tau]$. All elements below the diagonal, w_{st} ($s < t$), are checked against the opposing elements above the diagonal, w_{st} ($s > t$), and violations of WARP are identified wherever both are less than one. Under the null hypothesis, any such violation of WARP is interpreted as evidence of a change in preferences between time *s* and time *t*.

Measurement error can confound the nonparametric analysis when the preference information is obtained from the direct comparison of consumption bundles with similar total expenditure, which may lead the researcher to have less confidence for the test. An incorrect assignment of revealed preference in the case of similar expenditure bundles may affect the violation rate.

To allow for the measurement error, Afriat (1967) proposed removing the preference information obtained from the direct comparison of consumption bundles with similar total expenditure by modifying the *DRP* relationship as follows:

(1) $a\ DRP(e)\ b$ if and only if $e * p_a q_a \geq p_a q_b$,

where *e* is a value between zero and one. When using the Afriat's index, an inappropriate assignment of direct preference due to measurement error will not cause WARP violations between consumption bundles with similar total expenditure. Famulari (1995) included one more condition in the *DRP* relationship in addition to the Afriat's index. He defines commodity bundles *a* and *b* to be considered similar if the two bundles' total expenditures and budget shares at *a*'s prices are sufficiently similar. His index accounts for measurement error by assigning no revealed preference relationship to sufficiently similar pairs of consumption bundles.

To account for the measurement error arising from such situations that trivially respect or trivially violate the WARP axiom, based on the studies by Afriat and Famulari, the WARP test is modified as follows:

(2) t *DRP* s if and only if $p_t q_s / p_t q_t \leq e$,

where e can have any value between one to zero. If e is equal to one, this is the standard *DRP* relation. By specifying e to a value close to one but less than one, the preference information obtained from the comparison of consumption bundles with similar expenditure can be removed. This may affect both WARP-consistent and WARP-violating comparisons. Therefore, violations of WARP are identified wherever both are less than e when comparing elements below the diagonal, w_{st} ($s < t$), against the opposing elements above the diagonal, w_{st} ($s > t$).

Transitory nonlinear shocks, such as fads, may affect preferences, causing a violation of the WARP even in the absence of a systematic change in preferences. In addition, measurement errors and erroneous assumptions of aggregation, separability, or utility maximization can cause a WARP violation. Thus, a rejection of the Axioms can be triggered without a structural change occurring, causing a Type I error. Therefore, if one or more preference reversals are noted, given some possibility of such non-systematic factors, a further test is required to verify whether such reversals are due to a structural change or those other factors, and to identify the structural break point. Frechette and Jin's (2002) method provides such a test. In their test, the null hypothesis states that transitory nonlinear shocks or other errors cause the violations of WARP. The alternative is that a structural change caused the violations. Their test proceeds by splitting the whole sample into "late" and "early" portions based on a potential break point, z. Correspondingly, the matrix **W** needs to be split into three partitions. The *early partition* is the upper left corner, including elements w_{st} such that both s and t pertain to the early portion of the sample (s, $t < z$). The *late partition* is the lower right corner, including elements w_{st} such that both s and t pertain to the late portion of the sample (s, $t \geq z$). The third partition, or *spanning partition*, includes the lower left and upper right corners of the matrix, including elements w_{st} such that s and t span the sample ($s < z \leq t$ or $t < z \leq s$). In each partition, the numbers of violations are calculated. The logic behind this test is that if the structure of utility is fixed over the sample, then there exists an unconditional probability of observing a violation due to transitory nonlinear shocks or other errors, and the probability is the same in each partition unless the structure of utility shifts systematically at some time z, causing a structural change.

Frechette and Jin used the Kruskal-Wallis (K-W) statistic, a rank sum test, to determine whether the probability of observing a violation differs from partition to partition. Within their specification, if the probability of WARP violation differs between any pair of partitions in a statistically significant way, then it indicates a structural change. Violations in the three partitions are treated as draws from three separate distributions resulting in either a violation or a non-violation. The null hypothesis is that the three distributions are identical, i.e., no structural change in preferences but some WARP violations due to transitory shocks or other errors, whereas the alternative hypothesis is that not all the distributions are the same, i.e., a structural change in preferences with WARP violations caused by the structural change.

If no preference reversal is noted in the WARP test, then a Type I error cannot be made. The absence of any WARP violations suggests stable preference. However, finding no WARP violation does not necessarily guarantee intransitivity of preference. We need a further test, such as the Strong Axiom of Revealed Preference (SARP), to see intransitivity of the demand system. The SARP tests if some bundles *a*, *b*, and *c* together imply that *a* is revealed preferred (denoted *R*) to *b*, *b R c*, and *c 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**.

If one fails to find any violation in both WARP and SARP tests, it is possible to “rationalize” the data, to use Varian’s (1982) term. Then, the data set can be said to have been generated by the maximization of a utility function by the representative consumer, and the demand is stable.

Data

Data in this study consist of the monthly amounts of per-household consumption and the monthly average retail prices of beef, pork, and chicken. The data cover all areas in Japan. The unit of consumption is *gram*, and unit of average price is *yen*. The data start from January 1988 and end in June 2002. The total observations amount to 174. The data are obtained from *Japan Statistical Yearbook*: *Table of Yearly Amount of Expenditures, Quantities, and Average Prices by Commodities per Household*, provided by the Japan Statistical Association. Fish data are also added for the separability test between meat and fish groups. The fish data have the same nature as the meat data and were collected from the same source.

The quantities of meats consumed are displayed in Figure 1. Beef consumption had been increasing and pork and chicken consumption had been decreasing until 1996. Since 1996, the situation reversed; beef consumption is decreasing, pork consumption is increasing, and chicken consumption is at a recovering stage. The figure suggests that the point of reverse matches the timing of the U.K. government's announcement in March 1996, and the remarkable acceleration of the changes coincides with the BSE outbreak in Japan in September 2001. The graph for beef consumption seems to suggest that beef consumption in 2002 is rebounding to recover toward the long-term trend. However, the graph itself does not provide any economic interpretation about preferences. We need a systematic analysis that captures price and substitution effects on the demand behavior to derive any meaningful implication. The graph simply provides a rough idea that Japanese consumers could have been gradually affected by the BSE outbreak in Europe and that they could be affected the most significantly by the outbreak in their own country.

Using per-household data may yield a better performance than per-capita data in the revealed preference test and separability test, for two reasons. First, the revealed preference test needs an acceptable assumption that the commodities being analyzed constitute a group separable from other commodities. The assumption of separability is more intuitively appealing in the context of household budgets rather than individual budgets (Hayes, Wahl, and Williams, 1990). Second, for an empirical test for the separability between fish and meat groups, this study adopts the AIDS model. Deaton and Muellbauer (1980) derived the exact aggregation property of the AIDS model based on a household cost function and not on that of individual members of the household. Thus, per-household data might fit better to the setting of the AIDS model.

Separability Test between Fish and Meat in Japan

Aggregation and separability of demand data have been hot issues because they may lead the analysis to misleading interpretations and implications. Even when individual preferences are stable, per capita demands could appear unstable if aggregation bias exists or a relevant good is excluded. The data in this study come from per-household demand and may invoke the same aggregation problem as per-capita demand data. To mitigate the aggregation bias problem, this study assumes the existence of a representative consumer who makes food expenditure decisions for her (or his) household. The representative consumer might be a housewife in the representative household when we consider Japanese lifestyle. The assumption lends us, as Chalfant and Alston (1988) argued, to test stability of demand under the assumption that the data have been generated by a representative consumer who maximizes a stable utility function over the meat products, subject to a constraint on her (or his) expenditure. When we deal with an aggregated data set over a cross-section, the aggregation assumption may cause a bias in empirical analysis. For example, Young (1996) argues that an aggregation of just two consumers, who individually satisfy WARP, may violate the axiom. Therefore, as mentioned in the third section, given possible bias from erroneous aggregation assumption in addition to other non-systematic factors, the timing and pattern of the violations might be more important than the specific number of violations in interpreting the results. Therefore, if one or more preference reversals are noted, then a further test is required to verify whether such reversals are due to a structural change or because of those other factors. More emphasis might be given to the results from the second test than those from the first WARP test in inference about the effects of the BSE outbreak in Japan on consumers' preferences.

For the separability issue, it is assumed that meats constitute a weakly separable group from other commodities, including fish in Japan. A separability test is performed to check the validity of the assumption because the role of fish in the meat-purchasing decision of Japanese consumers has been controversial. Japan is the largest fish-consuming country in the world and fish has a closer relationship to the meat group than to any other commodities. Therefore, fish may not be separable from meats in household demands. In this case, the separability assumption will cause a bias in the analysis, which implies the necessity of a formal test for the separability. In this study, we perform a separability test developed by Hayes, Wahl, and Williams (1990).

Hayes, Wahl, and Williams conducted a separability test in fish and meat consumption of Japanese buyers and reported that the weak separability assumption is acceptable. However, the sample period of the data used in their study, which ends in 1986, does not synchronize with that of our data, which starts from 1988. Therefore, we conducted the separability test for the sample period in this study. Following Hayes, Wahl, and Williams, the separability test is performed using the cost function of a linear approximate AIDS (LA-AIDS) model. The AIDS model provides an arbitrary first-order approximation to any demand system, satisfies the axioms of choice exactly, aggregates perfectly over consumers, has a functional form which is consistent with known household-budget data, and can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters (Deaton and Muellbauer, 1980).

The separability test utilizes the following restriction that is implied by quasi-separability of the cost function and is written in terms of known shares and estimated parameters of the AIDS budget share system:

(3) $$\gamma_{rim} = E_{ri}\, \gamma_{rm},$$

where r and m denote meat and fish groups, respectively; i denotes each meat; the fish group is treated as a single commodity,[6] eliminating the need for a subscript; γ_{rim} is the estimated cross-price parameter between each meat and fish group in an AIDS model, in which individual meat and fish group shares are dependent variables; E_{ri} is the expenditure share of a particular meat within the meat group; γ_{rm} is the cross-price parameter between the meat group and fish group in a more aggregate AIDS model in which meat and fish group are specified as a commodity, respectively.

The budgetary shares of meat and fish in the LA-AIDS model have been specified using two different demand systems. The first specifies each individual meat and whole fish group as single commodities, respectively. The second is a more aggregated system in which the meat group is treated as a single commodity, like the fish group. Let the first model be named AIDS-1 and the second model AIDS-2. The parameters of both budget systems, AIDS-1 and AIDS-2, are estimated using an iterated nonlinear-seemingly unrelated regression (IT-SUR) method. From AIDS-2, the estimate of the cross-price parameter between the meat and fish group, γ_{rm}, is derived. It is plugged into equation (3), and the AIDS-1 model is re-estimated with implementation of the restriction implied by equation (3), producing a restricted AIDS-1. Now, we have estimates from both unrestricted and restricted AIDS-1 models. The residuals from the two different AIDS-1 models are used to derive a likelihood ratio (LR) test statistic.

Sample data used for the separability test were truncated in September 2001 because we expect that there might be a structural break in the Japanese consumers' demand for meat in September 2001, or the following month. The calculated LR statistic for the truncated sample is 6.71, which is smaller than the five percent significance level of the chi-square distribution with three restrictions (7.815). The test was performed again for the whole sample of the data to see whether including post-outbreak observations produces qualitatively different results in the separability test. The LR statistic is 6.88, which is also smaller than the five percent significance level (7.815). The test results suggest that the null hypothesis of the separability between meat and fish in Japan cannot be rejected, and the restriction of equation (3), implied by quasi-separability, is accepted by the data. In sum, the weak separability assumption is acceptable whether or not we truncate the sample in September 2001.

Application of Revealed Preference Test to Japanese Meat Demand Data

Testing whether there are switches in Japanese consumers' preference for meat after the BSE outbreak and whether the switches of preference are caused by an undergoing structural change or temporary demand shocks is important because the issue of structural change might be at the center of debate about the BSE effects on the meat industry in Japan, meat trade, and future policies of meat-importing and -exporting countries. If Japanese consumers' preference for meat has shifted from beef to pork or poultry, then meat producers, processors, retailers, and etc. should accept the Japanese consumers' reduced loyalty to beef. In order to maintain their market shares, beef-exporting countries need to inform and convince Japanese consumers that their meats are safe. On the other hand, if no structural change is found, the decrease of beef consumption in recent months can be considered to be temporary.

An additional concern beyond the aggregation and separability issues in a structural change test for market demand is the nature of the alternative hypothesis. An insufficient number of data observations may hinder economists from interpreting the exact nature of structural change. However, this study uses monthly data for 15 years, reducing the concern. Another source of an incorrect alternative hypothesis is the number of possible influences. According to the international and Japanese media reports about the Japanese consumers' reactions due to the BSE outbreak, one can notice that the event is the most significant shock in Japanese consumers' meat demands during the sample period. Refer to, for example, Japan Times, September and October, 2001, and *Livestock, Dairy, and Poultry Outlook*, in 2001 and 2002, the Economic Research Service (ERS) of USDA.

The alternative hypothesis can now be proposed that changes in Japanese consumers' preference for meat started from March 1996, as a result of the U.K. government's announcement, but the most severe changes occurred around September 2001, causing a structural change.

The matrix **W** described in the third section is constructed with the dimension of 174×174. The first row gives the costs of buying 174 different bundles at January 1988 prices; the second row, the costs of the same bundles at February 1988 prices; and so on. To reduce measurement error arising from assigning *DRP* relation for the consumption bundles with similar expenditure, we specified e to be 0.99 as specified in the study by Famulari (1995). Under the null hypothesis of the WARP test, all observed choices are consistent with maximization of the same utility function of the representative consumer. If the null hypothesis is rejected and the alternative is accepted, then it suggests that there have been switches from beef to pork or chicken due to the health concern caused by the BSE outbreak.

The result of the WARP test for the whole sample period is displayed in the first row in Table 1. It shows that there is a total of 88 violations of WARP, i.e., switch of preferences, out of 15,051 comparable pairs. There was a total of 126 violations of WARP when e is specified to be one, which corresponds with the standard *DRP* relation, which shows that measurement error contributes to violations of WARP. In the WARP test, even one violation would have been sufficient to reject the null hypothesis of stable utility. The hypothesis of stable preferences can be rejected. However, this does not necessarily mean that we should accept the alternative hypothesis because, among the violations, some may be due to switches of preferences caused by the BSE outbreak and others may be due to fads, other transitory nonlinear shocks, or erroneous aggregation and utility maximization assumptions. Note that the maintained alternative hypothesis is that violations are mainly due to the BSE outbreak in Japan, and therefore most of such switches are related with observations in recent months after the event.

Considering non-systematic factors, such as nonlinear shocks and erroneous assumptions, the timing and pattern of the violations might be important information in inferences about the effects of the BSE outbreak on consumers' preferences. For checking the timing and pattern of the violations, two additional procedures are completed. First, the WARP test is repeated within subsets of the whole sample. Second, the WARP violations in the whole sample W_1 are specified for each month.

The results from the WARP test on sub-samples are displayed in Table 1. W_1 denotes the WARP test for the whole period of the data. W_2 through W_8 indicate the test for sub-samples made by subtracting one-year length of observations in recent months. For example, W_2 ranges from January 1988 to June 2001, W_3 ranges from January 1988 to June 2000, and so on. The procedure is repeated until we have a sub-sample that ranges from January 1988 to June 1995, based on the alternative hypothesis. The results in Table 1 show that as we remove one-year length of observations, making the sub-sample W_2, the number of violations decreases dramatically from 88 to 7, and the ratio of violations to the total comparable pairs is also reduced from 0.0058 to 0.0005. This indicates that most of the WARP violations are related to observations after June 2001. To be more specific about the timing of such violations, the sub-sample W_2 is slightly changed such that it ends in August 2001, a month before the timing of the BSE outbreak in Japan. From this modified sub-sample of W_2, we found 7 violations, which is quantitatively the same result as those in original W_2's. This suggests that most of the WARP violations that occurred are related to the post-crisis observations. The results support the alternative hypothesis that Japanese consumers have been affected most significantly by the BSE outbreak in their country. From W_2 to W_7, the ratio of violations does not change much, and W_8 has only two violations. The results imply that the BSE outbreak in Europe and the U.K. government announcement on March 1996 may have caused temporary nonlinear shocks to Japanese consumers' meat preferences. The other few early violations may be due to other nonlinear demand shocks or erroneous assumptions in the test. The results also imply that a large impact occurred after September 2001, which might cause a systematic change of consumers' preferences.

The WARP test on sub-samples is performed in the opposite direction. Sub-samples, W'_2 through W'_7, were constructed by subtracting one-year length of observations from the beginning period of the sample. That is, W'_2 ranges from January 1989 to June 2002, W'_3 ranges from January 1990 to June 2002, and so on. What we intend to examine through this opposite procedure is that the ratio of violations to the total comparable pairs will increase as we remove observations from the beginning period of the sample, as long as our alternative hypothesis is acceptable, i.e., most of the WARP violations are related with post-outbreak observations. The results that are also presented in Table 1 support the results from the first procedure. As we delete observations in the beginning period, the ratio does not decrease, rather it increases from 0.0058 to 0.0128. This is intuitively plausible because as the sub-sample changes from W'_2 through W'_7, the comparable pairs in each sub-sample decrease but violation pairs cannot be reduced if most violations are related to post-crisis observations.

As the second procedure, the WARP violations in the whole sample W_1 were specified. Out of the total 88 violations of WARP, 81 violations are related with the ten months that range from September 2001 through June 2002; 21 violations are related with the observation in October 2001, and there were 15 violations with November 2001, 14 violations with January 2002, 8 violations with December 2001, 7 violations with February 2002, 6 violations with June 2002, and 3 violations with September 2001, 3 violations with March 2002, 3 violations with May 2002, and 1 violation with April 2002. This implies that most significant changes occurred from October 2001 through February 2002, and the structural break point would be October 2001.

In addition to the WARP tests, the test suggested by Frechette and Jin was performed to verify whether the violations are caused by a structural change or non-systematic factors such as transitory nonlinear shocks, or erroneous aggregation and utility maximization assumption, and further to specify structural break point. The null hypothesis of this test is no structural change in consumers' meat consumption pattern. The test is performed by partitioning the WARP matrix and calculating a series of Kruskal-Wallis statistics for each possible break point, as explained in the third section. Figure 2 shows the profile generated by the estimated K-W statistic for each potential break point, z. There are two K-W statistics that are above the five and one percent critical values[7] for a sample size of 174 (15.7 and 19.0, respectively); specifically 20.937 in September 2001 and 21.538 in October 2001. The sample maximum occurred in October 2001 rather than September 2001, which suggests a time gap between the outbreak and consumers' systematic responses to the event. This is consistent with the results from the second procedure that the observation most significantly contributing to violations of WARP is October 2001. Now, the alternative hypothesis that violations are mainly related with the post-outbreak observations, and such switches are due to a structural change in Japanese consumers' preferences in meat consumption responding to the BSE outbreak in Japan can be accepted, and the most likely break point is October 2001.

In sum, there were a total of 88 violations of WARP, with occurrences intensively related to the post-crisis observations. Japanese consumers' preferences for meat changed systematically, responding to the BSE outbreak, which supports the alternative hypothesis. The peak of the K-W statistics occurred in October 2001, which corresponds to the month following the BSE outbreak.

The validity of this conclusion should be based on the robustness of the results to seasonality, since a seasonal pattern is observed in Japanese meat consumption data. More meats are consumed in the end of each year and less meats are consumed in the beginning of the year. The revealed preference test and the Frechette and Jin test were meant to be invariant to seasonality. However, albeit 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. For example, rejections when comparing summer months to winter months may be more frequent than rejections when comparing summer months to summer months if seasonality interferes with the tests. Frechette and Jin evaluated the robustness of the revealed preference test to seasonal variation by checking whether seasonality caused excess violations of WARP. The results of their test demonstrate no statistical evidence of excess violations of WARP caused by seasonality.

This study conducted the test on the Japanese meat consumption data set. The WARP matrix, W, is grouped into two sets by season (within season and across season) and the percentages of violations in the two sets are 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. The average percentage of violations of the within-season set is 0.0101 and that of the across-season set is 0.0099, suggesting no evidence that seasonality affected the revealed preference tests. For a concrete inference, a test is performed to see whether the two sets of violation percentages are statistically different or not, using the Wilcoxon rank sum test in the one-way nonparametric analysis of SAS. The null of no difference between the two groups' WARP violation frequency is rejected if the estimated statistic is less than 2.0 at the five percent significance level, according to the sample sizes $n_1 = 4$ and $n_2 = 6$. The result is that the test statistics is 22.6; therefore, the null is not rejected at the five percent significance level. It implies that the percentages of violations in the two sets are statistically the same. Thus, the argument that the revealed preference test was meant to be invariant to seasonality is acceptable in our data set.

Chalfant and Alston (1988) point out that a drawback of testing a hypothesis with the nonparametric revealed preference approach is the unknown power of the test. That is, even when in the presence of substantial structural change, one may fail to reject the hypothesis of stable preference. The empirical results suggest that the null of the stable preference was rejected and the alternative hypothesis of a structural change after the BSE outbreak was accepted, which implies that a Type II error may not be a significant problem in this analysis. Therefore, concerns about the power of the nonparametric revealed preference test might not be significant in this study.

Summary and Conclusion

This paper used a nonparametric approach for testing a structural change in the meat demand of Japanese consumers. The WARP test was used to test the stability of preferences, and results showed that there are switches in Japanese consumers' meat preferences that are not explained by relative price or expenditure changes. Considering possible errors in aggregation and utility maximization assumptions in addition to transitory nonlinear shocks, the timing and pattern of WARP violations might be important information in inferring the effects of the BSE outbreak on consumers' preferences. Therefore, the timing and pattern of the violations was checked by the WARP test on sub-samples and by specifying the WARP violations in the whole sample for each month. Further, to verify whether such reversals are due to a structural change or because of those other non-systematic factors, the WARP matrix is partitioned and K-W statistics are derived. Empirical results show that most WARP violations are related with post-crisis observations, that they are due to a structural change in Japanese consumers' meat preference, and that the timing of the structural change is synchronized with the month following the BSE outbreak in Japan.

The results of this study might be particularly relevant to the Japanese government, beef producers, and processors in Japan. The effect of the BSE outbreak was an immediate, sharp drop in Japanese consumption of both domestic and imported beef. According to *Japan Statistical Yearbook 2002*, Japanese consumers have significantly reduced beef consumption and increased pork and chicken consumption. Together with the results from our study, this implies that Japanese consumers want less risky meat, so their preferences for meat are moving away from beef to its substitutes. Hinged on further discoveries of BSE infected cattle, a rebound of beef consumption may not occur in the short-term or even in the long-term.

The results of this study might contain important information for the policy makers and traders of meat-exporting countries that export beef or its substitutes to Japan. According to

Livestock, Dairy, and Poultry Outlook (ERS/USDA), Japanese demand for U.S. beef has decreased while the demand for U.S. pork has increased, despite the facts that the United States has not reported any case of BSE and that the Safeguard in Japan increases the minimum price of imported pork. The results from this study implies that the BSE outbreak in Japan might be the primary factor driving Japanese import demand away from beef to pork. Consumers' acceptance of BSE-free beef as a substitute for their domestic beef, Wagyu, along with further discoveries of BSE infected cattle, will be an important factor for Japanese import demand for beef and its substitutes in coming years.

Additional research might be conducted to test structural change in meat trade between Japan and the exporting countries, based on the structural break point indicated by this study. Furthermore, quantifying the potential welfare losses of beef producers, exporters, and consumers associated with the BSE outbreak will also be valuable research to add to the literature about food safety-related studies.

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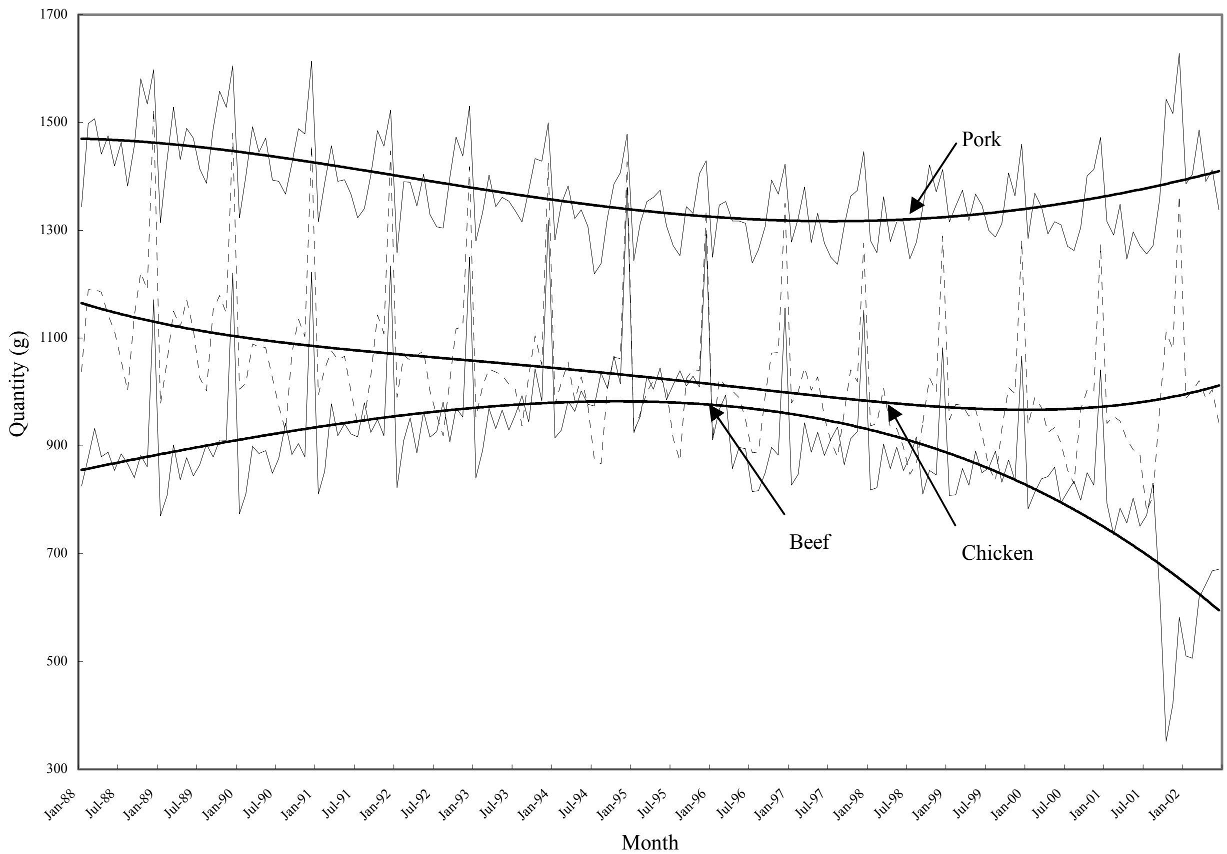

Figure 1.
Meat (Beef, Pork, and Chicken) Consumption of Japanese Consumers (1988~2002)

Data are time series for per-household consumption of beef, pork, and chicken in Japan. The data are monthly from January 1988 through June 2002. To see long-term trend, a polynomial trend line is constructed for each series and denoted by a bold line.

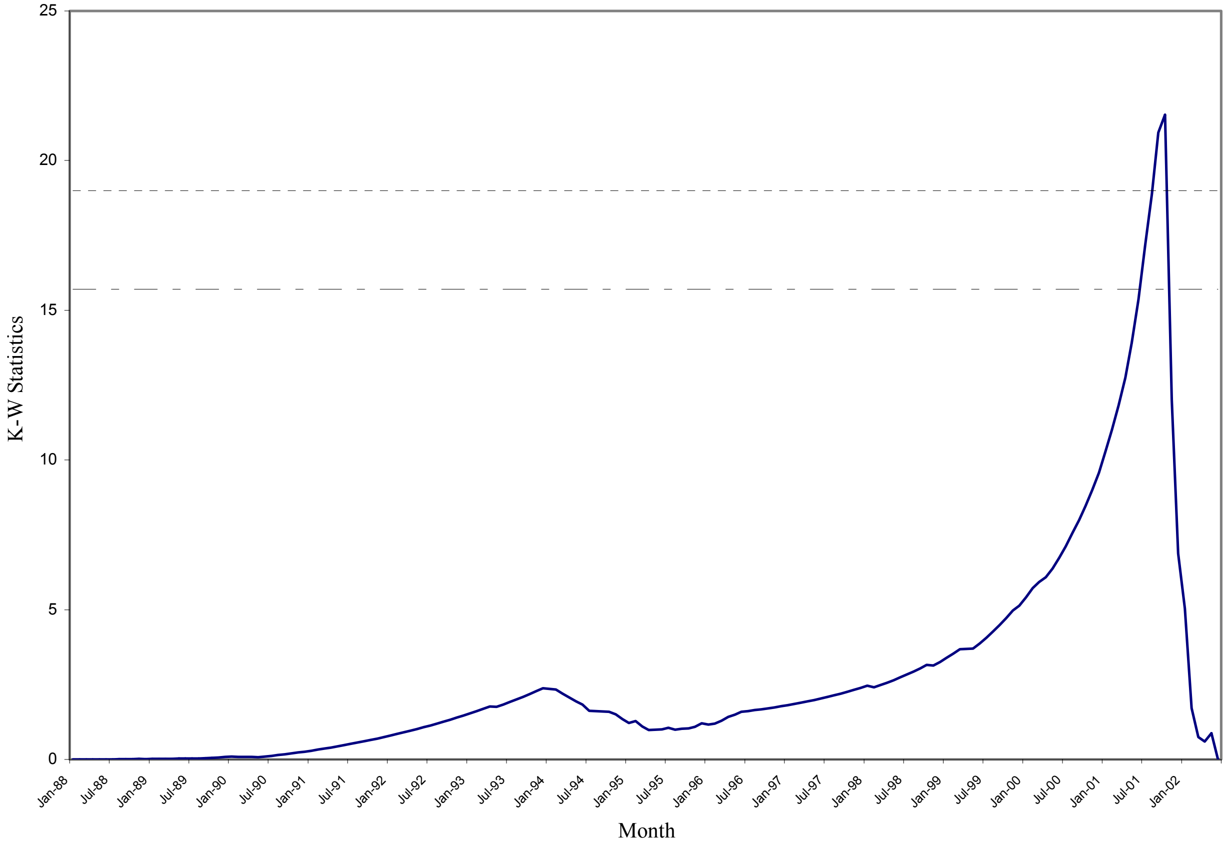

Figure 2.
Relationship Between the Adjusted K-W statistics and z; Structural Change in Japanese Meat Demand (January 1988 to January 2002)

_____ K-W Statistics, ------ 99% Critical Value, _ . _ . _ 95% Critical Value

The null hypothesis in each z is no structural change in Japanese meat consumption.
The number of z is equal to the observation number minus three, i.e., τ-3 KW statistics.

Table 1.
Results of WARP Test with Japanese Meat Consumption Data.

Data Range of Sub-Time Series	Number of Total Comparable Pairs	Number of Violation Pairs	Ratio of Violations to Total Comparable Pairs[a]
First Procedure[b]			
W_1: 1988 January ~ 2002 June (174)[c]	15,051	88	0.0058
W_2: 1988 January ~ 2001 June (162)	13,041	7	0.0005
W_3: 1988 January ~ 2000 June (150)	11,175	7	0.0006
W_4: 1988 January ~ 1999 June (138)	9,453	7	0.0007
W_5: 1988 January ~ 1998 June (126)	7,875	4	0.0005
W_6: 1988 January ~ 1997 June (114)	6,441	3	0.0004
W_7: 1988 January ~ 1996 June (102)	5,151	3	0.0005
W_8: 1988 January ~ 1995 June (90)	4,005	2	0.0004
Opposite Procedure[d]			
W'_1: 1988 January ~ 2002 June (174)	15,051	88	0.0058
W'_2: 1989 January ~ 2002 June (162)	13,041	75	0.0057
W'_3: 1990 January ~ 2002 June (150)	11,175	71	0.0063
W'_4: 1991 January ~ 2002 June (138)	9,453	68	0.0071
W'_5: 1992 January ~ 2002 June (126)	7,875	68	0.0086
W'_6: 1993 January ~ 2002 June (114)	6,441	68	0.0105
W'_7: 1994 January ~ 2002 June (102)	5,151	66	0.0128

Note:
[a] The ratio is calculated from dividing the number of violation pairs by the total comparable pairs.
[b] The first procedure is a WARP test for sub-samples made by deleting observations on the current period.
[c] The values in parentheses are the number of observations for each sub-sample.
[d] The opposite procedure is a WARP test for sub-samples made by deleting observations on the beginning period.

Endnotes

[1] The U.K. government announced on March 20, 1996 that there is a possible link between consumption of BSE-infected beef and the development of a new variant of its human equivalent, known as Creutzfeldt-Jacob disease (vCJD).

[2] According to the Economic Research Service (ERS), the U.S. Department of Agriculture (USDA), 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 import market.

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

[4] The United States and Australia have never reported any BSE outbreak in the countries. For more information about the claim of BSE-free countries, see, for example, (1) BSE documents, *Geographical Risk of Bovine Spongiform Encephalopathy Rating*, Department of Agriculture Fisheries & Forestry-Australia. The original report was made by Food Safety Division of European Commission. Refer the web-site, http://europa.eu.int/comm/food/index_en.html, (2) *Ag Journal, Country Roads Network*, February 7, 2002: BSE in Japan Affect U.S. Producers, http://www.agjournalonline.com/, and (3) 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.

[5] 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/.

6 Defining "fish" as a single commodity may cause a bias because Japanese consumers spend almost as much on fish as they spend on all other meats combined and the Japanese government collects much more detailed data on consumption and prices of different fish species than on meats (Hayes, Wahl, and Williams, 1990). However, due to the limitation of data accessibility to each individual fish (monthly frequency), the separability test is performed with combining all fish species as a group.

7 Under the null hypothesis of the K-W test, the test statistic has an asymptotic Chi-Squared, χ^2, distribution, with two degree of freedom. However, a standard χ^2 critical value cannot be used for rejecting the null hypothesis because the appropriate critical value for the maximum of K-W statistic, denoted by K-W*, is not 5.99, which is the standard Chi-Squared five percent significance level. For example, if the total number of observations, T, is 100, then there are 97 different K-W statistics on the profile graph. Note that τ = 1,2, and 100 correspond to empty partitions and they are therefore inadmissible break points. If each of the 97 statistics were independently and identically distributed χ^2 random variables, then the probability that the K-W* < 5.99 would be $(.95)^{97}$ = 0.0069, meaning that 99.31 percent of the time K-W* > 5.99. The appropriate critical value is Z, where $[\text{prob(K-W} > \text{Z)}]^{T-3} = 0.95$ (0.99) for the five (one) percent significance level. For T = 100, the critical values of five and one percent significance levels are 15.09 and 18.34.