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**The Effect of Food-Safety Related Information on Consumer Preference:
The Case of the BSE Outbreak in Japan**

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Abstract

This paper uses a nonparametric approach for testing whether there is a structural change in the meat demand of Japanese consumers due to the BSE (mad-cow disease) 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 is currently unstable and has undergone a structural change, synchronized with the BSE outbreak in Japan in mid-September 2001.

Keywords: BSE (Mad-Cow Disease); the Revealed Preference Test; WARP; structural change

Highlights

Food safety is an important issue for consumers today. 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.

The objective of this study is to test Japanese consumers' responses to the BSE outbreak to evaluate if they have undergone a structural change in their preferences for meat, using two nonparametric tests. One is the weak axiom of revealed preference (WARP) test and the other is a test created by Frechette and Jin (2002). 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. 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' responses.

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. The null hypothesis of this study is that Japanese consumers' preferences for meat are stable even after the BSE outbreak in their own country and therefore there is no structural change in their tastes. The alternative hypothesis is that Japanese consumers had been gradually affected by the BSE outbreak in Europe, and that they were affected most significantly by the outbreak in the country. We expect that the most possible structural break point coincides with the timing of the BSE outbreak in Japan in September 2001, rather than the time of the British 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.

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 changes in relative prices of commodities and different time points. The WARP matrix is partitioned and K-W statistics are derived to distinguish whether the switches in consumers' tastes are transitory or accompany a structural change. Empirical results show that violations of the stable preferences are due to a structural change in Japanese meat consumption and the timing of such change is synchronized with the outbreak of BSE in Japan in mid-September 2001.

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

Hyun J. Jin, Changyou Sun, and Won W. Koo*

INTRODUCTION

Food safety is an important issue for consumers today. In addition to the traditional socio-economic factors influencing consumers' choices, such as income level, product prices, and lifestyle, food safety significantly affects buyers' preferences [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' demands 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 of the BSE outbreak and consumers' responses have been completed mostly by European economists. Ashworth and Mainland (1995) reviewed economic consequences of a 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 paying 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 pertained to BSE; their results showed that television publicity has a negative impact on beef expenditure, in favor of pork. Henson and Mazzocchi (2002) assessed the impact on the U.K. agribusiness sector of the government's announcement on March 20, 1996, 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. Their results indicate that firms in a number of sectors were negatively affected by the announcement, most notably processors of

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beef. However, no study has been completed to test the stability of consumers' preferences for meat products after the BSE outbreak.

The objective of this study is to test Japanese consumers' responses to the BSE outbreak to evaluate if they have undergone a structural change in their preferences for meat, using two nonparametric tests. 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).

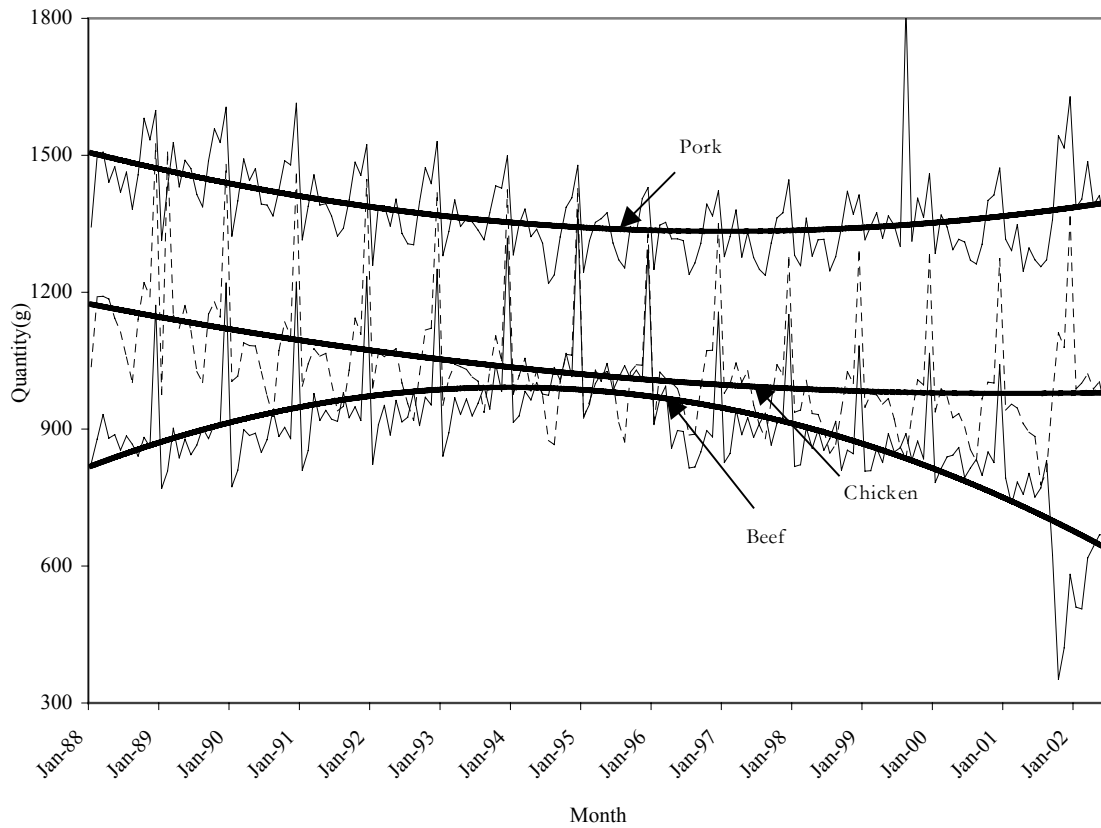
Japanese consumers are chosen because of the following three reasons. First, Japan is the primary importer of beef from major beef-exporting countries, such as the United States and Australia. Second, Japan is a leading beef-producing and -consuming country in Asia, and their response can be a basis 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' responses.

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 onward, 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 British government's announcement, and that they were affected most significantly by the outbreak in their own country. We expect that the most possible structural break point coincides with the timing of the BSE outbreak in Japan in September 2001, rather than the time of the British 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 results of this study might contain important information for beef-exporting countries as well as for the Japanese government, beef producers, and processors. The United States and Australia have been the largest beef-exporting countries to Japan, and therefore, the results can be used for the two countries to construct marketing strategies to enhance their beef exports to Japan.

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 meats and fisheries 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, and implications for U.S. beef exports to Japan are reviewed in the seventh section. A summary and conclusion follow in the last section.

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



Note: Data are per household consumption time series of beef, pork, and chicken in Japan. The monthly data are from January 1988 to June 2002. The data are provided by the Japan Statistical Association. In order to see long-term trend, a polynomial trend line is constructed for each series and denoted by a bold line.

A BRIEF REVIEW OF THE 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. After its discovery, a series of research projects led scientists to the conclusion that the bovine agent had originated from a scrapie agent that is known to be present in sheep.

The occurrence of BSE in cattle reached epidemic proportions in Europe by 1992, with more than 1,000 reported cases. Within the 13-year period, from 1987 to 2000, the total number

of infected cattle swelled to 180,000 in the UK, Ireland, Portugal, France, and Switzerland.¹ Consumers were suddenly alerted to the danger of human-infection on March 20, 1996, by an announcement from the government of the United Kingdom. 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 "mad-cow" 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 British government may not have caused a large impact on Japanese consumers because beef consumption in Japan comes mostly from domestic production and imports from so-called BSE-free countries, such as the United States and Australia.² 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 British government's release may have been gradual rather than pronounced.

Amid signs of spreading mad-cow disease across Europe, Japan has tried to prevent the disease from entering its borders. It has done this by restricting blood donations from people who have lived in Britain and banning E.U. beef and food made from processed beef and bull sperm that is used for breeding. 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 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

¹See, 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.

²For more information about the claim of BSE-free countries, see, for example, (1) *CNN news*, September 10, 2001: Japan Reports First Case of Mad Cow, <http://www.cnn.com/2001/WORLD/asiapcf/east/09/10/japan.madcow/> (2) *Ag Journal, Country Roads Network*, February 7, 2002: BSE in Japan Affects 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. <http://www.aphis.usda.gov/lpa/issues/bse/bse.html>

ranging from 5% to 50% due to the concern over BSE. Consumption of beef in Japan has fallen sharply, and beef prices have dropped significantly.³

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 so that one-in-four Japanese consumers stopped eating beef, and restaurants reported a slump in sales of beef dishes. 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.

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 or random coefficients on the specified demand system. A structural change is implied when stability of parameter estimates is rejected in a conventional significance level, or when difference between residuals of sub-samples is statistically and economically acceptable. This approach provides the economic significance and implications of a structural change. However, all such tests are conditional on the functional form being specified. Thus, the hypothesis being tested by the approach is stable preference only in a specific form of demand system. Economists usually face an unknown underlying structure of the data at hand, and thus, one may need to check all possible demand systems in the approach.

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 well-behaved utility function is rejected, and structural change can be accepted.

This study adopts the nonparametric approach. Previous applications of the nonparametric test include: Varian (1985); Swofford and Whitney (1986); Ashenfelter and Sullivan (1987); Thurman (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); Frechette and Jin (2002); and Ueda and Frechette (2002).

³ 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/>

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 $U(\cdot)$ that is nonsatiated, continuous, monotonic, and concave that rationalizes the data. The null hypothesis also assumes that shocks to $U(\cdot)$ are linear, so they do not affect the marginal rates of substitution (MRS) between any two goods.

This study specifically uses a weak form of the Axiom called the WARP. Let R denote “revealed preferred.” When a bundle a is revealed preferred to any other bundle b that could have been purchased instead, if any such bundle b is also revealed preferred to bundle a , it implies both $a R b$ and $b R a$. Then, the WARP is violated. This could occur only if indifference curves had shifted, given the maintained hypotheses.

The WARP test begins by establishing the price and quantity vectors, denoted by \mathbf{P} and \mathbf{Q} , respectively, for k goods observed for the sample period from time l to time τ . The next step of the WARP test is the construction of a matrix \mathbf{W} with elements $w_{st} = p_s' q_t / p_t' q_s$, where p_t and q_t denote price and quantity at time $t \in [l, \tau]$. All elements below the diagonal, w_{st} ($s < t$), are checked against the opposing elements above the diagonal, w_{ts} ($s > t$), and violations of WARP are identified wherever w_{st} and w_{ts} are both 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 .

The revealed preference approach has a restriction to linear shocks, which implies an important weakness of the approach. Linear shocks leave MRS unchanged for each bundle. In reality, the MRS is stochastic and tastes are fickle from period to period. Transitory nonlinear shocks, such as fads, may affect preferences, causing an apparent violation of the WARP even in the absence of a systematic change in preferences. 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, then a further test is required to verify whether such reversals are due to a transitory nonlinear shock or a structural change, 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 cause the violations of WARP. The alternative is 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 \mathbf{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, 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) test, a rank sum statistic, 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., preferences are stable with some WARP violations due to transitory shocks, whereas the alternative is that not all the distributions are the same, i.e., preferences are unstable with some WARP violations caused by a 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 preferences. However, finding no WARP violation does not necessarily guarantee intransitivity of preferences. 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 $a R b$, $b R c$, and $c R a$. The SARP is violated if such intransitivity of the three bundles is found in the matrix \mathbf{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*, denoted by g , 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 the *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 has reversed; beef consumption is decreasing, pork consumption is increasing, and chicken consumption is at a recovering stage. The figure suggests that the point the reverse began matches the date of the 1996 British government’s announcement, and the remarkable acceleration of the changes coincides with the BSE outbreak in Japan. The graph for beef consumption seems to suggest that beef consumption in 2002 is rebounding to recover in 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 separable group from other commodities. The assumption of separability is more intuitively appealing in the context of household budgets than in individual budgets [Hayes, Wahl, and Williams (1990)]. Second, for an empirical test for the separability between fisheries and meats, this study adopts the AIDS method. 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 FISHERIES AND MEATS 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 the lifestyle of the Japanese people. The assumption leads 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.

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. 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 fisheries have 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 demand 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 also conducted the separability test for this study's sample data. 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:

$$\gamma_{rim} = E_{ri} \gamma_{rm}, \quad (1)$$

where r and m denote meat and fish groups, respectively; i denotes each meat; fish group is treated as a single commodity,⁴ 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 the 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 as 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 cross-price parameter between the meat and fish group, γ_{rm} , is derived. It is plugged into Equation (1), and the AIDS-1 model is re-estimated with implementation of the restriction implied by Equation (1), 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. The calculated LR statistic is 6.88, which is smaller than the 5% significance level, 7.815, of the chi-square distribution with three restrictions. Hence, the null hypothesis of the separability between meat and fish in Japan cannot be rejected. This indicates that the restriction of Equation (1), implied by quasi-separability, is accepted by the data.

APPLICATION OF REVEALED PREFERENCE TEST TO JAPANESE MEAT DEMAND DATA

Testing whether there are switches in Japanese consumers' preferences 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

⁴ 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.

future policies of meat-importing and -exporting countries. If Japanese consumers' preferences for meat have shifted from beef to pork or poultry, then meat producers, processors, retailers, 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 in 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 an 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 international and Japanese media reports about the Japanese consumers' reactions to the BSE outbreak, one can notice that the event is the most significant shock in Japanese consumers' meat demands during the sample period. For example, refer to the *Japan Times*, September and October, 2001, and *Livestock, Dairy, and Poultry Outlook*, in 2001 and 2002, by the Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA). The alternative hypothesis can now be proposed that changes in Japanese consumers' preferences for meat started in March 1996, as a result of the British government's announcement, but the most severe changes in the consumers' demands for meat, causing a structural change, occurred around September 2001.

The matrix \mathbf{W} described in the third section is constructed with the dimension of 174×174 . The first column gives the costs of buying 174 different bundles at January 1988 prices; the second column, the costs of the same bundles at February 1988 prices; and so on. 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 has been at least a switch from beef to pork or chicken due to the health concern caused by the BSE outbreak.

The result of the WARP test for the sample period is displayed in the first row of Table 1. It shows that there is a total of 126 violations of WARP, i.e., switch of preferences, out of 15,051 comparable pairs. 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, and even errors in data collection and manipulation. Even one violation would have been sufficient to reject the WARP null hypothesis of stable utility. The hypothesis of stable preferences can be rejected.

Note that the maintained alternative hypothesis is that violations are mainly due to the BSE outbreak in Japan, and therefore most such switches happened in recent months after the event. In order to check the timing of the violations, the WARP test is repeated within subsets of the whole sample. The results are also displayed in Table 1. W_1 denotes the WARP test for whole period of the data. W_2 through W_8 indicate the test for sub-samples made by subtracting one-year length of observations from 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.

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

Data Range of Sub-Time Series	Number of Comparable Pairs	Number of Violation Pairs	Percentage of Violations^a
<i>First Procedure^b</i>			
W ₁ : 1988 January ~ 2002 June (174) ^c	15,051	126	0.0083
W ₂ : 1988 January ~ 2001 June (162)	13,041	28	0.0021
W ₃ : 1988 January ~ 2000 June (150)	11,175	24	0.0021
W ₄ : 1988 January ~ 1999 June (138)	9,453	19	0.0020
W ₅ : 1988 January ~ 1998 June (126)	7,875	10	0.0012
W ₆ : 1988 January ~ 1997 June (114)	6,441	9	0.0013
W ₇ : 1988 January ~ 1996 June (102)	5,151	6	0.0011
W ₈ : 1988 January ~ 1995 June (90)	4,005	4	0.0009
<i>Second Procedure^d</i>			
W' ₁ : 1988 January ~ 2002 June (174)	15,051	126	0.0083
W' ₂ : 1989 January ~ 2002 June (162)	13,041	111	0.0085
W' ₃ : 1990 January ~ 2002 June (150)	11,175	105	0.0093
W' ₄ : 1991 January ~ 2002 June (138)	9,453	102	0.0107
W' ₅ : 1992 January ~ 2002 June (126)	7,875	102	0.0129
W' ₆ : 1993 January ~ 2002 June (114)	6,441	101	0.0156
W' ₇ : 1994 January ~ 2002 June (102)	5,151	97	0.0188

Note:

^a Probability of violation is calculated from dividing pairs of violation by 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 second procedure is a WARP test for sub-samples made by deleting observations on the beginning period.

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 W₂, the number of violations decreases dramatically from 126 to 28, and the probability of violation out of comparable pairs is also reduced from 0.0083 to 0.0021. This indicates that most of the WARP violations are related to data observations after June 2001. The results support the alternative hypothesis that Japanese consumers have been affected most significantly by the BSE outbreak in their country. From W₂

to W_7 , the probability of violation does not change much, and W_8 has only four violations. The results imply that the BSE outbreak in Europe and the British government's announcement on March 1996 have affected Japanese consumers' meat preferences, but that they caused few violations of WARP. By contrast, a large impact occurred after September 2001, causing a systematic change of preferences.

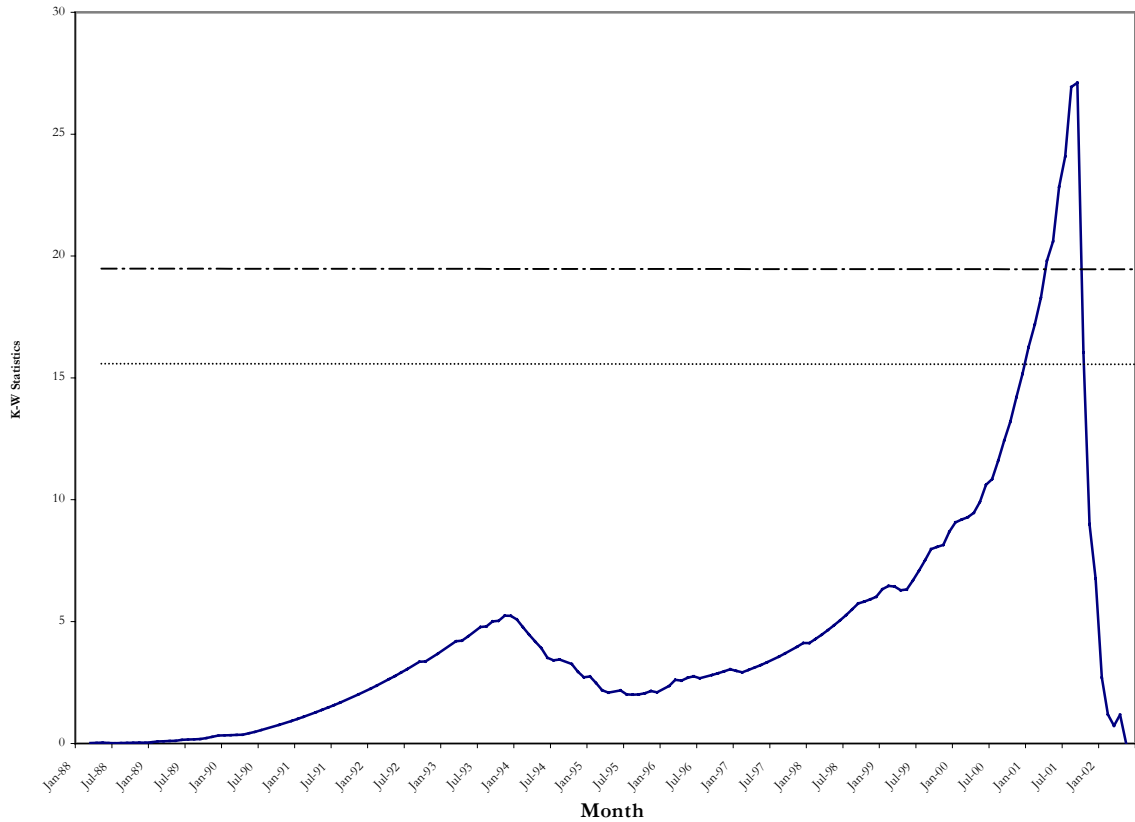
The WARP test for sub-samples to determine whether the violations occurred in recent months is performed by a different procedure. In this second procedure, W'_2 through W'_7 were constructed by subtracting one-year length of observations from the beginning period of the sample, respectively. That is, W'_2 ranges from January 1989 to June 2002, W'_3 ranges from January 1990 to June 2002, and so on. The results of the second procedure are also presented in Table 1. What we intend to examine through the second procedure is that the probability of violation 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 to observations in recent months. The results of the second procedure support the results from the first procedure. As we delete observations in the beginning months, the probability does not decrease, rather it increases from 0.0083 to 0.0188. This is intuitively plausible because as the sub-sample changes from W'_2 through W'_7 , comparable pairs in each sub-sample decrease, but pairs of violation cannot be reduced if the violations have occurred in recent months.

Although there are 126 violations out of 15,051 comparable pairs, it is still possible that all the violations could be due to transitory nonlinear shocks, fads, or errors in data manipulation. Thus, we need a further test to analyze whether the violations in recent months are caused by transitory nonlinear shocks or a structural change. The test proceeds by partitioning the WARP matrix and calculating a series of K-W 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 . The sample maximum of 27.107, which occurred in September 2001, exceeds the 5% and 1% critical values⁵, 15.7 and 19.0, for a sample size of 174. Therefore, the null hypothesis of no structural change can be rejected at the 1% significance level, and the most likely break point is September 2001.

⁵ Under the null hypothesis of the K-W test, the test statistic has an asymptotic Chi-Squared, χ^2 , distribution, with two degrees of freedom. However, a standard χ^2 critical value cannot be used 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 5% 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 $\tau = 1, 2$, 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% of the time $K-W^* > 5.99$. The appropriate critical value is Z , where $[\text{prob}(K-W > Z)]^{T-3} = 0.95$ (0.99) for the 5% (1%) significance level. For $T = 100$, the critical values of 5% and 1% significance levels are 15.09 and 18.34.

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



Note:

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

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

Summarizing the results from the WARP test and the estimated K-W statistics, there were a total of 126 violations of WARP, occurring sporadically since 1996 and more intensively in recent months in 2001 and 2002. The frequency of violations increased in the latter part of the sample. The patterns indicate that preferences shifted systematically in recent months. The peak of the K-W statistics occurred in September 2001, which corresponds exactly to the outbreak of BSE in Japan, supporting the alternative hypothesis.

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 at 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, \mathbf{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 0.0098, 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 5% significance level, according to the sample sizes $n_1 = 4$ and $n_2 = 6$. The result is that the test statistic is 23.0; therefore, the null is not rejected at the 5% 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. Empirical results show that there are 126 violations, suggesting that a Type II error is not a significant problem in this analysis. Therefore, concerns about the power of the nonparametric revealed preference test are not significant in this study.

POTENTIAL IMPLICATIONS FOR U.S. BEEF EXPORTERS

Since beef imports were liberalized in April 1991, tariff rates in Japan have been progressively lowered. As a result, beef registered the greatest growth among Japanese meat imports. According to the production, supply, and distribution (PS&D) database (ERS/USDA), the portion of imported beef in the total Japanese beef consumption has been increasing to roughly 65% during the last three years. The imported beef market in Japan is virtually monopolized by the United States and Australia, which together account for close to 95% of Japan's beef imports. Due to advanced freezing technology and the ability to supply special cuts of grain-fed beef, which is generally preferred by Japanese consumers, the United States has recently caught up with Australia. As a result, the United States now enjoys a slight lead over Australia in beef exports to Japan.⁶

⁶ See, for example, the monthly report *Livestock, Dairy, and Poultry Outlook*, the ERS of the USDA.

U.S. beef exports to Japan had been increasing until the year 2000. However, exports began to soften by spring of 2001, possibly due to tighter U.S. supplies, higher prices, and the appreciating dollar. Higher U.S. prices were exacerbated by a 10% increase in the U.S. dollar value against the Japanese currency. In the second half of 2001, the discovery of BSE in Japan added to the downward trend.⁷

The effect of the BSE outbreak was an immediate, sharp drop in Japanese consumption of both domestic and imported beef. According to *the Japan Statistical Yearbook 2002*, Japanese consumers have significantly reduced beef consumption and increased pork and chicken consumption. Japanese demand for U.S. pork has increased, according to *Livestock, Dairy, and Poultry Outlook* of the ERS/USDA, despite of the fact that the Safeguard in Japan increases the minimum price of imported pork. The BSE outbreak might be the primary factor driving Japanese demand for pork.

Health concerns of Japanese consumers and their response to imported beef could play prominent roles in determining imports of U.S. meat in coming years. Consumers' preferences may hinge on further discoveries of infected cattle and acceptance of so-called BSE-free beef from the United States and Australia as a substitute for their domestic beef, Wagyu. The empirical results of this study show that Japanese consumers' preferences for meats have been undergoing structural change. Therefore, a rebound of beef consumption may not occur in the short-term.

If the structural change results in behavior similar to that of European consumers, a rebound in beef exports can be expected. European consumers consider imported beef as a substitute for BSE-concerned European beef. Thus, it is possible that beef exporters in the United States and Australia could benefit from Japanese consumers' skepticism of their domestic beef. It has never been reported that meat and bone meal, the presumed source of BSE, have been feed ingredients in cattle in either the United States or Australia. Thus, beef exports by both countries to Japan could eventually return to pre-BSE outbreak levels of growth if neither country reports any BSE-infected cattle. However, Japanese consumers have historically preferred their domestic beef to imported beef. Therefore, Japanese consumer attitudes could evolve in a different way than European consumer attitudes.

Even if consumers' attitudes follow the same path in both Japan and Europe, the expectation of U.S. beef exports to Japan is still vague because U.S. beef exports have suffered disproportionately in comparison with Australia due to the strong U.S. dollar and the perception that Australian grass-fed beef has a lower risk of BSE. The prospects of U.S. exports, therefore, may also depend on Japanese consumers' recognition of U.S. beef against Australian beef and changes in U.S. dollar value.

⁷ See, for example, *Livestock, Dairy, and Poultry Outlook*, the ERS of the USDA; *Japan Trade Statistics*, Japan Customs; and *Agro-Trade Handbook 2001*, Japan External Trade Organization (JETRO).

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 changes in relative prices with respect to commodities and different time points. The WARP matrix is partitioned and K-W statistics are derived to distinguish whether the switches in consumers' tastes are transitory or accompany a structural change. Empirical results show that violations of the stable preferences are due to a structural change in Japanese meat consumption and the timing of such change is synchronized with the outbreak of BSE in Japan in mid-September 2001.

Additional research might be conducted to test structural change in the 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 added to the literature on food safety-related studies.

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